Office of the Associate Administrator
for Commercial Space Transportation (AST)
Federal Aviation Administration (FAA)
Department of Transportation (DOT)

PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR COMMERCIAL LAUNCH VEHICLES

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DRAFT

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LIST OF ACRONYMS AND ABBREVIATIONS

A-50	Aerozine-50
AAM	Annual Arithmetic Mean
ACS	Attitude control system
Al_2O_3	Aluminum oxide
Ar	Argon
AST	Office of the Associate Administrator for Commercial Space Transportation
Br	Bromine
Ca	Calcium
CAA	Clean Air Act
CeTAP	Cetacean and Turtle Assessment Program
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
Cl	Chlorine
cm	Centimeters
CO	Carbon monoxide
CO_2	Carbon dioxide
CSLA	Commercial Space Launch Act
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
dB	Decibels
dBA	Decibels (A-weighted)
DOT	Department of Transportation
EA	Environmental Assessment
EPA	Environmental Protection Agency
EIS	Environmental Impact Statement
ELV	Expendable Launch Vehicle
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FRP	Fiber Reinforced Plastic
GEO	Geosynchronous Earth Orbit
GTO	Geosynchronous Transfer Orbit

H	Atomic hydrogen
H_2	Hydrogen
HAP	Hazardous air pollutant
HCl	Hydrogen chloride
He	Helium
H_2O	Water
Hz	Hertz
IIP	Instantaneous Impact Point
in	Inches
K	Potassium
km	Kilometer
L_{dn}	Day-night noise level over a 24 hour period
LEO	Low Earth Orbit
LH2	Liquefied hydrogen
LOX	Liquefied oxygen
LV	Launch vehicle
MMH	Monomethylhydrazine
MMPA	Marine Mammal Protection Act
Mn	Manganese
N_2	Nitrogen
Na	Sodium
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMHC	Nonmethane hydrocarbons
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
N_2O_4	Nitrogen tetroxide
NPDES	National Pollutant Discharge Elimination System
O	Atomic oxygen
O_2	Oxygen
O_3	Ozone
ODS	Ozone depleting substance
OSHA	Occupational Safety and Health Administration

P	Phosphorus
PBAN	polybutadiene acrylonitrile
PEIS	Programmatic Environmental Impact Statement
Pb	Lead
PCB	Polychlorinated Biphenyls
PM_{10}	Particulate matter of 10 microns or less is diameter
PPA	Pollution Prevention Act of 1990
ppm	Parts per million
psf	Overpressure measured in pounds per square foot
REEDM	Rocket Exhaust Effluent Diffusion Model
RCRA	Resource Conservation and Recovery Act of 1976
RP1	Jet fuel
RV	Reentry Vehicle
SARA	Superfund Amendment and Reauthorization Act of 1986
SLC	Space launch complex
SO_2	Sulfur dioxide
SPEGL	Short-term public emergency guidance level
SRM	Solid rocket motor
TLV	Threshold limit value
TSCA	Toxic Substances Control Act
TTS	Thrust Termination System
UNEP	United Nations Environmental Programme
µg/m3	Micrograms per cubic meter
UV	Ultraviolet
VAFB	Vandenberg Air Force Base
WSMR	White Sands Missile Range
Xe	Xenon
Zn	Zinc

EXECUTIVE SUMMARY

The FAA's office of the Associate Administrator for Commercial Space Transportation (AST) is responsible for issuing launch licenses for unmanned commercial launch vehicles (LVs).[a] Issuing a launch license is considered a federal action and is subject to review as required by the National Environmental Policy Act of 1969, as amended (NEPA) (42 U.S.C. 4321 et seq.). This Draft Programmatic Environmental Impact Statement (PEIS) evaluates the potential environmental consequences of launching commercial LVs. It will be used by AST, in conjunction with other documentation, to assess the environmental impacts of the operation of commercial LVs, and to support licensing of such operations. The primary commercial use for LV launches is placement of communication satellites in space; other examples of commercial uses of LVs are remote sensing and scientific research, such as materials processing in a microgravity environment. The demand for communication satellites has been steadily growing due to the increased demand for existing satellite services and new technologies (i.e., mobile communications services, and the next generation broadband interactive television and radio).

This PEIS covers commercial launches from both existing government launch facilities and non-federal launch sites. This PEIS will update and replace AST's 1986 Programmatic Environmental Assessment (EA), as announced in the Federal Register January 10, 1996 Notice of Intent (61 FR 763). This PEIS assesses the potential environmental effects of launches from ignition, liftoff and ascent through the atmosphere to orbit, and the disposition of rocket components down range. Any remaining launch activities (including vehicle assembly and payload preparation prior to liftoff, payload functioning during useful life, and payload reentry whether controlled or uncontrolled) are outside the scope of this PEIS.[b] The scope is limited to the assessment of environmental consequences of the launch activities listed; no construction activities (e.g., development of new launch sites or modification of existing ones) are assessed. The information in this PEIS is not intended to address all site-specific launch issues. Any required site-specific environmental documentation would be developed as needed. In addition, this PEIS does not include site-specific, localized effects. Localized effects and the cumulative impact of these localized effects at an individual launch site can only be appropriately analyzed in the environmental review of a launch site operator. Environmental reviews in support of launch licenses address the environmental impacts associated with issuing a license, while environmental reviews in support of launch operator licenses address the local and cumulative impact of launches from the specific site. Both types of reviews (i.e., launch licenses and launch operator licenses) are expected to tier from this PEIS in the future.

ES.1 The Preferred Alternative and Additional Alternatives

This PEIS analyzes the environmental impacts of the preferred alternative, licensing commercial LVs for launches, and two alternatives. Licenses for launches will be issued in accordance with the specifications set out in the Commercial Space Launch Act and other supporting regulations. The licensing of launches is considered a major federal action and is therefore subject to NEPA review. As part of this review process five alternatives were considered to the preferred alternative. Three of these alternatives are not specifically addressed in this PEIS because they were not determined to be feasible.

[a] Launch vehicles (LVs) in this Programmatic Environmental Impact Statement are comprised of expendable launch vehicles (ELVs) that jettison or release expended stages (usually over water) with no intent to recover or reuse these components and reusable launch vehicles (RLVs) that have reusable stages or components that can return to Earth and be recovered.

[b] The payload is the item that an aircraft or rocket carries over and above what is necessary for the operation of the vehicle in flight.

The other two alternatives include more environmentally-friendly propellant combinations alternative and a no action alternative. Under the more environmentally-friendly propellant combinations alternative, AST would emphasize licensing LVs that produce fewer air emissions of concern. Under the no action alternative, AST would not issue licenses for commercial LV launches. This PEIS analyzes environmental impacts by examining the following characteristics of LVs and LV launch profiles:

- payload capacity (the mass an LV can lift into a particular orbit),
- types of propulsion systems (the mechanisms that change the momentum of the vehicle by changing the velocity of the air moving through the system), and
- launch platforms - ground, air, or sea-based.

ES.2 Potential Impacts of the Preferred Alternative

Various environmental criteria were used to determine the overall environmental impact associated with each alternative. The environmental impacts associated with the preferred alternative include three major categories, atmospheric, noise, and other environmental impacts. The atmospheric category includes an analysis of impacts to air quality, acid rain, ozone depletion, and global warming. The noise category includes an analysis of launch, in-flight and reentry noise on various human and animal receptors. The final category specifically addressed, other environmental effects, includes an analysis of impacts to water, land, and biota, as well as analyzing socioeconomic, historical, cultural, and archaeological considerations. Specifically, potential impacts in the atmosphere were examined in the troposphere (atmospheric layer extending from the earth's surface to 10 or 20 kilometers), stratosphere (atmospheric layer extending from the troposphere to 55 kilometers), mesosphere (atmospheric layer extending from 45 or 55 kilometers to 80 or 85 kilometers), and ionosphere (atmospheric layer extending upwards from 70 or 80 kilometers). Potential noise impacts from launch activities include the effects of acoustic energy on receptors (e.g., people, wildlife, and on structures). Socioeconomic and environmental justice effects of the preferred alternative were also considered.

Other environmental effects were analyzed based on generic localized environments. These effects included the climate and atmosphere of the launch site, land resources, water resources, and biological resources. The environmental characteristics of six different types of ecosystems representing various potential commercial LV launch locations throughout the U.S. were used to describe the range of potential impacts of commercial space launches. A marine mammals strike probability analysis was also conducted. The PEIS is *not* site-specific; any required site-specific environmental documentation would be developed as needed.

ES.2.1 Atmospheric Impacts of the Preferred Alternative

The atmospheric impacts of the preferred alternative will be addressed for all levels of the atmosphere. The primary potential impacts to the troposphere may result from the ground cloud, the cluster of emissions formed from the ignition of rocket motors and the resulting launch of the LV. Other potential impacts to the troposphere could result from accidents on the launch pad or during flight. In the stratosphere, LV emissions could potentially affect global warming (the greenhouse gas effect) and depletion of the stratospheric ozone layer. In this analysis, no impacts are predicted to the mesosphere during nominal launches because air emissions are not an issue in this region of the atmosphere. Regarding the ionosphere, some exhaust products from LVs generated during launch from Earth to space have been found to have a temporary effect on electron concentrations in the F layer of the ionosphere.

ES.2.2 Noise Impacts of the Preferred Alternative

The noise impact of the preferred alternative will also be considered, particularly the impact of sonic booms. A sonic boom is the noise created by a shock wave occurring when an aircraft is traveling overhead faster than the speed of sound. The three concerns regarding sonic booms' effects on humans are health, startle, and annoyance. This analysis found no health impacts from the preferred alternative. While annoyance data appear to be inconclusive, people may be more sensitive to sonic booms than previously thought. The types of interference and activities people are involved in affect annoyance, and a wide range in estimating percent annoyed is reported in the literature. However, preliminary data indicate that people perceive sonic booms as more intrusive than aircraft noise at comparable levels.

Birds are most sensitive to noises at far higher frequencies than those associated with LV launches. Birds may be startled by impulsive noises created by LV launches, but this effect will most probably be of short duration. Mammals seem to be less disturbed by noise than birds, but startle effects can occur. Sonic booms from LV launches also impact underwater environments. These types of booms represent a threat of physical and physiological impairment to marine mammals in the vicinity of the water surface, particularly if these mammals are in the relatively restricted impact zone of the boom.

Structural damage may occur as a result of overpressure caused by the preferred alternative. Overpressure is a transient pressure, that occurs as a result of an explosion, that exerts a force that exceeds the standard atmospheric pressure. Damage to glass, plaster, roofs, and ceilings at exposed buildings might result. In well-built and maintained buildings, glass will receive the primary damage. Approximately one in 10,000 panes may be broken at an overpressure of four pounds per square foot (psf). LVs can possibly produce an overpressure in the two to three psf range.

ES.2.3 Local Impacts of the Preferred Alternative

<u>Atmosphere.</u> Characteristics of the local atmosphere substantially affect the air quality impacts of rocket launches. These characteristics include wind speed and direction, temperature, humidity and rainfall, atmospheric stability and mixing heights (i.e., the altitude of the boundary layer or an inversion layer), and the topography of the area. The wind speed may affect the area over which the ground cloud may be dispersed. The amount of rainfall and humidity may increase the likelihood and quantity of acid rain (rain with an acidity (pH) of less than 5.6) from hydrogen chloride (HCl) in the troposphere rained out of solid propellant rocket launch exhaust, reducing the HCl load in all layers of the Earth's atmosphere. The mixing area is the atmospheric region where pollutants and emissions tend to remain. Atmospheric stability will also affect the impacts of rocket launches. The more stable the atmosphere, the longer the ground cloud may hang over a particular area without much dispersion.

<u>Land and Water.</u> The environmental impacts to local land resources from the preferred alternative are mainly limited to impacts to soil from the formation of a launch ground cloud (from solid rocket motors) that produces acidic deposition. Soil impacts include temporary increases in available metals and temporary decreases in pH. Surface water impacts include temporary increases in available metals and temporary decreases in pH.

<u>Biological Resources.</u> Chronic impacts could result from subtle alterations in habitat and potentials for bioaccumulation (a progressive increase of the bodily content of a toxic compound) of pollutants that may be released into the environment from LV-related activities. Impacts to biological resources from repeated LV deposition close to the source can include fish kills and occasional mortality of terrestrial fauna. Flora in the vicinity of the launch site may be affected by the launch exhaust products or from

combustion products associated with catastrophic events. Vegetation changes from repeated deposition close to the source include loss of sensitive species, decline in shrub cover, and increasing bare ground.

Launches also present a potential for acute impacts to fish and wildlife in the vicinity of the launch pad resulting from noise, blast debris, heat, and toxic chemicals. The possibility of acute noise impacts would depend on the size and type of LVs being launched. In general, the potential for impacts on biological resources from LV heat exhaust is limited by the use of appropriate mitigation measures such as berms or shields. The toxic chemical of primary concern is HCl associated with the use of solid propellants.

Regarding debris, there is a remote possibility that jettisoned or separated motors, stages or fairings from an expendable launch vehicle (ELV), an unmanned space vehicle with the ability to operate in, or place payloads in outer space that is intended to be used only once, could strike a marine mammal when it enters the ocean during nominal flight operations. According to the marine mammals strike probability analysis conducted for this PEIS, less than 0.5 mammals per year are expected to be hit, even when all launch activity is summed, and a summation is done across all species over both oceans.

ES.2.4 Socioeconomic Impacts of the Preferred Alternative

Development and growth of the commercial LV industry will have a beneficial economic impact. Jobs associated with the commercial LV industry tend to be technology-based and require highly skilled workers with specialized skills and education.

ES.2.5 Environmental Justice Impacts of the Preferred Alternative

Because this is a programmatic EIS, analysis of environmental justice effects of the preferred alternative must be general and not site-specific in nature. Thus, environmental justice effects within the scope of this analysis are related to the socio-economic effects. Because this analysis assumes that the preferred alternative will result in *positive* socioeconomic effects, including maintaining or increasing current employment levels in the U.S. space industry, it is assumed that these positive effects will at a minimum not produce disproportionate *negative* impacts on minority or low-income populations.

ES.3 Potential Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

Potential environmental impacts associated with the more environmentally-friendly propellant combinations alternative were analyzed in three major categories: atmospheric impacts, noise impacts, and other environmental effects. Specifically, potential impacts in the atmosphere were examined in the troposphere, stratosphere, mesosphere, and ionosphere. Potential noise impacts of launch activities on receptors were analyzed for human beings, wildlife, and structures. Socioeconomic and environmental justice effects of this alternative were also considered.

This alternative is defined as preferentially licensing those rockets that are not solely propelled by SRMs. This would reduce the total number of U.S. commercial launches projected from 1998 through 2009 from 436 to 134. The number of launches using liquid, liquid/solid, or hybrid propellant systems was assumed to remain unchanged under this alternative. Thus, the total number of commercial, AST-licensed launches in the U.S. (i.e., programmatic launches) would decrease substantially under this alternative. It was assumed that the decrease in U.S. commercial launches that use only solid propellants would be compensated for by an increase in these launches elsewhere in the world.

ES.3.1 Atmospheric Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

Potential impacts in the atmosphere from this alternative were examined in the troposphere and stratosphere. No change was estimated relative to the preferred alternative for effects in the mesosphere and ionosphere. This alternative does not affect emissions in those regions of the atmosphere under the definition of the alternative as preferentially licensing those rockets that are not solely propelled by SRMs. It is important to note that conclusive data and analysis regarding the specific impacts of emissions from multi-propellant launch vehicles (e.g., liquid and solid combinations) currently do not exist. Because the environmental impacts related to combined emissions of multi-propellant LVs have not been adequately characterized at this time, this analysis relies on existing, available data on emissions from single propellant systems. Ongoing U.S. Air Force and industry research in this area may alter the future understanding of the cumulative atmospheric impacts of multi-propellant LVs and the relative atmospheric impacts of different types of propellant systems.

The specific HCl input to the stratosphere from rocket exhaust can be estimated if the HCl amount and its time-dependent releases along the ascent are known. Using the number of launches estimated in Section 2.0, but eliminating all launches using solely solid propellant systems in the troposphere and stratosphere, the emission load of HCl in the stratosphere for all U.S. commercial LV launches from 1998 through 2009 (a period of 12 years) is approximately 905 tons, and additional free Cl load is 12 tons. This averages to approximately 76 tons of HCl and Cl load to the stratosphere from U.S. commercial LV launches per year. (See Appendix A, Emission/Afterburning Products and Loads for a detailed methodology determining numbers and emissions loads.) In comparison, under the preferred alternative, the emission load of HCl in the stratosphere for all U.S. commercial LV launches from 1998 - 2009 is approximately 5,024 tons, and additional free Cl load is 67 tons. This averages to approximately 424 tons of HCl and Cl load to the stratosphere from U.S. commercial LV launches per year. Emissions of concern resulting from potential accidents on the launch pad and from activation of flight termination systems would also be reduced under this more environmentally-friendly propellant alternative, because rockets using only solid propellant systems would no longer be licensed and launched in the U.S. However, this reduction in emissions from avoided accidents was not quantified in this analysis.

ES.3.2 Noise Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

This alternative is anticipated to have fewer noise impacts than the minimal impacts associated with the preferred alternative.

ES.3.3 Local Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

The more environmentally-friendly propellant combinations alternative would reduce the impact of commercial launches on soils in the vicinity of launch pads. Space Shuttle and other government launches would still have an impact on soil pH, but the cumulative effects from these launches, as a result of fewer commercial launches involving only solid propellant, would not be as great. The prospect of additional local water impacts near a commercial launch site from licensed commercial launches would also be reduced. Additionally, coastal waters that could be affected in the event of an accident would experience reduced impacts.

Vegetation changes from the ground cloud at launch, as well as wildlife impacts from launch activities, would be reduced. However, the increased demand for launch sites could lead to construction of launch sites outside the U.S. These launch sites could potentially have a significant impact on biodiversity if they are sited on or near endangered or biologically fragile ecosystems (i.e., rain forest, habitats of endangered species). The probability of jettisoned ELV sections (e.g., spent SRMs, payload fairings) making direct contact with a marine species would remain remote under this alternative.

ES.3.4 Socioeconomic Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

Development and growth of the commercial LV industry would have a beneficial economic impact; limiting this development and growth by preferentially licensing a subset of LVs would reduce the magnitude of this beneficial impact relative to the preferred alternative.

ES.3.5 Environmental Justice Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

Because this is a programmatic EIS, analysis of environmental justice effects of this alternative must be general and not site-specific in nature. Thus, environmental justice effects within the scope of this analysis are related to the socio-economic effects. Because this analysis assumes that this alternative will result in *positive* socioeconomic effects (although less relative to the preferred alternative), including maintaining or increasing current employment levels in the U.S. space industry, it is assumed that these positive effects will at a minimum not produce disproportionate *negative* impacts on minority racial, ethnic, or economically-disadvantaged populations.

ES.4 Potential Impacts of the No Action Alternative

Because 49 U.S.C. Subtitle IX, ch. 701 -- Commercial Space Launch Activities, formerly the Commercial Space Launch Act (CSLA), requires commercial launches by U.S. entities to be licensed, the U.S. space launch industry would be unable to continue LV launch operations regardless of their location under the no action alternative. Chapter 701 requires AST to license a launch if the applicant complies and will continue to comply with chapter 701 and implementing regulations.
49 U.S.C. § 70105. One of the purposes of chapter 701 is to provide that the Secretary of Transportation, and therefore AST, pursuant to delegations, oversees and coordinates the conduct of commercial launch and reentry, and issues and transfers licenses authorizing those activities. 49 U.S.C. § 70104 (b) (3). The agency may prevent a launch if it decides that the launch would jeopardize public health and safety, safety of property, or national security or a foreign policy interest of the United States. 49 U.S.C. § 70104 (c).

Not licensing any U.S. commercial launches would not be consistent with chapter 701 in this context. In any event, the no action alternative could negatively impact the national security and foreign policy interests of the United States. Some U.S. government payloads have been launched by the U.S. commercial space launch industry. Therefore, if access to commercial LVs is not available, this overall limit in available capacity could, in a worst case scenario, impact the U.S. government's ability to launch needed payloads and negatively affect programs that rely on access to space. Additionally, parties that had planned to launch from U.S. launch sites would be forced to find alternatives, potentially exposing sensitive technologies to countries with competing economic and security interests.

Under the no action alternative, the same number of worldwide commercial LV launches would take place. However, because AST would cease issuing licenses for launches in the United States, the launches would take place from foreign locations. In the absence of access to commercial launches in the United States, it is likely that other countries with existing space launch programs (e.g., France, Russia, China, Canada) would significantly expand their programs to accommodate the excess demand. In addition, it is even possible that countries currently without existing space launch programs would initiate launching of commercial LVs to meet this demand.

ES.4.1 Atmospheric Impacts of the No Action Alternative

It is possible that if no LV launches could take place from the U.S. that fewer LVs would be launched overall worldwide unless existing foreign launch programs could expand rapidly to accommodate increased launch requirements. This would result in an overall decrease globally in rocket emissions potentially affecting the atmosphere. However, based on the comparison of capacity and propulsion systems, the transfer of launches from U.S. LVs to foreign LVs (e.g., Zenit, Proton, Ariane IV and V, Long March, H2, GSLV, PSLV, and M-V) could cause an increase in atmospheric emissions overall (this analysis is described in detail in Appendix A of this EIS). Any local effects that might be associated with LVs, such as the extremely small potential for acid rain and stratospheric ozone depletion, would occur outside the U.S. However, the potential for global warming and stratospheric ozone depletion would remain essentially the same based on the assumption that an equal number of launches would occur in either case.

ES.4.2 Other Impacts of the No Action Alternative

The prospect of noise impacts and sonic booms near U.S. launch sites would be eliminated. If no commercial LV launches occurred, there would be no impact on the soils in the vicinity of launch pads at U.S. launch sites. Space Shuttle and other government launches would still have an impact on soil pH, but the cumulative effects from these launches, absent the commercial launches, would not be as great. The prospect of local water impacts near the launch site would be eliminated. Additionally, coastal waters that could be affected in the event of an accident would no longer be potentially impacted.

Vegetation changes from the ground cloud at launch would be eliminated, as well as wildlife impacts from launch activities. However, the increased demand for launch sites could lead to construction of launch sites outside the U.S.[1] These launch sites could potentially have an impact on the world wide biodiversity if they were sited on or near endangered or biologically fragile ecosystems (i.e., rainforest or habitats of endangered species). Even if launch sites are not located on or near fragile ecosystems, the impact of building facilities to launch space vehicles while U.S. launch sites go underutilized is not an effective use of the world's resources. The probability of jettisoned ELV sections (e.g., spent solid rocket motors (SRMs), payload fairings) making direct contact with a marine species would remain remote.

ES.4.3 Socioeconomic Effects of the No Action Alternative

The no action alternative would have negative socioeconomic impacts by forcing all payloads currently planned for commercial launch in the U.S. to use foreign launch vehicles. As a result, U.S. jobs would be lost to foreign entities to support their launch activities and programs. It is possible that U.S. telecommunications companies and other U.S. space users would be given lower priority in launching satellites, creating a potential for scheduling problems and loss of competitiveness in the global technology market.

The U.S. economy would not enjoy the full potential benefits of high-technology jobs or multi-billion dollar revenues derived from the commercial space launch industry. Companies directly involved in providing commercial launch services would no longer be able to operate in that capacity and would be significantly affected. Companies that produce rocket engines or vehicle components could also experience a decline in revenue. The impact to hardware producers would be less severe than for service providers because: (1) the revenue stream from continued military launches would likely continue; and (2) the opportunity for sales of propulsion units and vehicle components overseas could improve because foreign launch providers would need more vehicles to meet the demand from the increase in U.S. payloads seeking their launch services.

Closing the commercial LV industry to the U.S. private sector would both foreclose potential domestic economic benefits and reduce U.S. international competitiveness. If technological advances are achieved during the development and use of foreign LVs, foreign enterprises would gain further advantages in marketing these new goods and services. Thus, foreign economies could possibly be stimulated, while the U.S. would lag behind, both economically and technologically.

ES.4.4 Environmental Justice Effects of the No Action Alternative

Because the no action alternative would have negative socioeconomic impacts that may result in a loss of U.S. jobs to foreign entities, it is possible that minority or low-income populations may suffer some disproportionate affects of these job losses.

ES.5 Potential Cumulative Impacts

Cumulative impacts are defined as the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions (40 CFR § 1508.7). Only the cumulative atmospheric impacts of commercial LVs combined with all other rocket launches worldwide were analyzed. Other cumulative impacts, including most cumulative noise and local environmental impacts, would be site-specific and are beyond the scope of this PEIS. These cumulative impacts would be considered in site-specific documentation.

This PEIS examines impacts and cumulative impacts from “programmatic” launches, or launches requiring licenses from AST. All other rocket launches, or “non-programmatic launches,” consist of U.S. government launches, foreign commercial launches, and foreign government launches. The potential for cumulative impacts from programmatic LV activity is assessed through a comparison to launch activity worldwide (i.e., programmatic and non-programmatic launches). The conclusion of many studies previously done on the cumulative environmental effects of rocket launches worldwide is that the effects of rocket propulsion on stratospheric ozone depletion, acid rain, toxicity, air quality, and global warming are extremely small compared to other industrial or man made impacts. This corresponds to the conclusions of this PEIS.

ES.5.1 Cumulative Atmospheric Impacts

The cumulative impact of all of tropospheric emissions loadings from launch activities is relatively insignificant compared with industrial and natural emissions loadings to the troposphere.

Furthermore, the cumulative impacts of rocket launches on global warming and depletion of the stratospheric ozone layer are insignificant compared to other global industrial sources. Even when accounting for both programmatic and non-programmatic (cumulative impact) carbon monoxide/carbon dioxide (CO/CO_2) loads combined, the cumulative impact of the preferred alternative on global warming is negligible compared to emissions loads from other industrial sources just in the United States. Similarly, the cumulative impact on stratospheric ozone depletion from rocket launches is far below and indistinguishable from the effects caused by other natural and man-made causes. In general, ongoing analyses of LV exhausts indicate that the potential for ozone depletion associated with LV exhaust to cause an increase in solar UV intensity near launch sites is extremely limited.

This PEIS does not predict any cumulative impacts to the mesosphere or ionosphere. The more rockets that are launched, the greater the potential for creating “holes” in the ionosphere; however, based on available data indicating that this effect is temporary, the cumulative impacts to the ionosphere are assumed to be minute.

When an accident occurs near the launch pad or a launch anomaly results in using in-flight termination capabilities (if equipped), there is a cumulative effect on air quality, potential global warming, and stratospheric ozone depletion. For accidents that occur in the stratosphere, HCl and nitrogen oxides (NO_x) emissions could potentially contribute to stratospheric ozone depletion, while CO_2 emissions could potentially contribute to global warming. These effects of an accident on ozone depletion and global warming would be greater with a larger capacity LV versus a smaller capacity LV. Although cumulatively, probabilities for accidents increase with the proportionate increase in launches considered, accidents are still rare events. Therefore, the overall cumulative impacts from accidents are insignificant as compared with other emission sources.

ES.5.2 Cumulative Noise Impacts

In general, the potential cumulative impacts of noise from rocket launches are expected to be local effects that are expected to impact the area around the launch pad. However, an important possible cumulative noise impact might include changes in the migrating route and habitat choice of certain marine mammals exposed to repeated occurrences of sonic booms from LVs. These sonic booms would occur in areas downrange of the launch pad.

ES.6 Irreversible And Irretrievable Commitment Of Resources

The launch of LVs requires the commitment of natural resources, including the consumption of mineral resources. No additional cultural resources, whether human or land resources, are expected to be committed to the launching of LVs beyond those that have been or will be addressed in site-specific NEPA documentation. Basic commitments of natural and cultural resources for commercial space launches are not different from those necessary for many other research and development programs; they are similar to the activities that have been carried out in previous space program activities over the past 25 years.

ES.7 Mitigation Actions

A variety of mitigation measures are recommended to prevent or reduce environmental effects associated with the preferred alternative. Monitoring is needed at individual launch sites, such as water sampling and analyses, archeological surveys of areas with historical artifacts, and biological species surveys by specialists to monitor the health and numbers of biological species of concern. In addition, it is assumed that all launch sites will comply with permit conditions imposed by regulatory authorities, which represent a substantial mitigation action. Other examples of suggested mitigation measures include: (1) appropriate noise control actions, including blast fences, berms, and launch timing/seasonal restrictions, as needed; (2) promoting the use of environmentally-friendly propellants, as feasible; (3) engaging in voluntary waste pollution prevention programs; (4) developing a comprehensive environmental management system; (5) working with stakeholders to avoid conducting launch activities in culturally or archeologically-sensitive areas to the maximum extent possible; and (6) implementing effective lighting policies to protect wildlife. Mitigation measures are discussed in further detail in Section 9 of this PEIS. This section further examines possible mitigation measures for noise and solid and hazardous waste. This section addresses ways to minimize adverse impacts to water quality, air quality, cultural and historical resources, and biological resources.

1. INTRODUCTION

1.1. Preferred Alternative

In recent years, the private sector has expressed heightened interest in launching space vehicles, projects that have previously been conducted only by the federal government. According to 49 U.S.C. Subtitle IX, ch. 701 -- Commercial Space Launch Activities, the development of commercial launch vehicles and associated services is in the national and economic interest of the United States. To ensure that launch services provided by private enterprises are consistent with national security and foreign policy interests of the U.S., and do not jeopardize public safety and the safety of property, the Department of Transportation (DOT), Federal Aviation Administration, (FAA) is authorized to regulate and license U.S. commercial launch activities. Within DOT and FAA, the Secretary's authority has been delegated to the office of the Associate Administrator for Commercial Space Transportation (AST). This authority extends to licensing of commercial launch vehicles (LVs)[c] and is considered to be a major federal action subject to the requirements of the National Environmental Policy Act of 1969, as amended, (NEPA) 42 U.S.C. § 4321, et seq.

1.2. Purpose and Need of Preferred Alternative

Launch licenses are needed to provide a mechanism for ensuring protection of public health and safety. U.S. laws and policy and international treaties recognize the technological and economic importance of developing space transportation. They also identify the requirement for the proper oversight and control of launch activities. Specifically, 49 U.S.C. ch. 701 encourages the development of a commercial space industry, and authorizes the Secretary of Transportation to oversee, license, and regulate commercial launch activities and to issue and transfer commercial launch licenses. The Secretary is charged with the responsibility to protect public health and safety, the safety of property, and national and foreign policy interests of the U.S. Thus, AST's launch review and licensing procedures are necessary to ensure that launch applicants meet conditions designed to protect the public health and safety, safety of property, and national security and foreign policy interests. These conditions include:

- securing the minimum amount of third-party liability insurance specified by DOT,
- adhering to launch safety regulations and procedures,
- complying with requirements concerning pre-launch record keeping and notifications, including those pertaining to federal airspace restrictions and military tracking operations, and
- complying with federal inspection, verification, and enforcement requirements.

1.3. Environmental Responsibility of FAA

Under the authority of the 49 U.S.C. Subtitle IX, ch. 701, AST determines whether to issue a launch license. Issuing a launch license is considered a major federal action and is subject to review as required by NEPA. This Draft Programmatic Environmental Impact Statement (PEIS) evaluates the potential environmental consequences of commercial launches. In February 1986, AST published a

[c] Launch vehicles (LVs) in this PEIS are comprised of both expendable launch vehicles (ELVs) that jettison or release expended stages over water with no intent to recover or reuse these components and reusable launch vehicles (RLVs) that have stages or components that can return to Earth and be recovered and reused.

Programmatic Environmental Assessment (EA) of Commercial Expendable Launch Vehicle Programs. The Programmatic EA addressed the programmatic aspects of commercial launches and has been used for environmental review of commercial launch applications to date. This PEIS will update and replace the existing EA.

This PEIS addresses the potential environmental impacts of launching LVs. It will be used by AST, in conjunction with other documentation, to assess the environmental impacts of the operation of commercial LVs, and to support licensing of such operations. AST may find it necessary to require a commercial launch license applicant to submit additional information to supplement this PEIS. Additional environmental documentation may be needed by AST in its licensing decisions, and that could include site-specific launch site environmental analyses and mission-specific information. Information such as the actual design of the launch vehicle and any payload, system testing and evaluation records, maintenance records, launch site range safety plans and procedures, emergency and countermeasures plans, critical failure mode and effects analyses, and mission-specific objectives may also be reviewed and evaluated by the AST as a part of the environmental review process.

1.4. Scope of this PEIS

This PEIS considers, at the programmatic level, the environmental impacts of licensing commercial LV launches. This PEIS analyzes in detail the potential environmental impacts of the estimated 436 commercial launches that will result from the proposed licensing program. Included in the analysis are potential environmental impacts resulting from ignition and lift-off to payload separation and the deposition of rocket components downrange. Site-specific, localized environmental effects will be subject to an individual review. For the purpose of this document, LVs are unmanned space vehicles with the ability to operate in, or place payloads in, outer space; LVs also include suborbital rockets. LVs do not include "amateur rocket activities"conducted at private sites[d] or all reentry vehicles. Reentry vehicle means a vehicle designed to return from earth orbit or outer space to Earth, or a reusable launch vehicle designed to return from earth orbit or outer space to Earth, substantially intact. 49 U.S.C. § 70101 (13). For purposes of this PEIS, reentry vehicles means those that are not reusable launch vehicles. LVs are used to transport government, scientific, and commercial payloads (e.g., communication satellites, other spacecraft, scientific experiments) from Earth into various orbits around Earth, including Low Earth Orbit (LEO), elliptical orbit, and geosynchronous transfer orbit (GTO), as well as to the moon and other bodies in this solar system. Sounding rockets, used to lift payloads to altitudes as high as 1,500 km, are also included in this PEIS.

Objects in LEO follow a path between the earth's atmosphere and the bottom of the Van Allen belts, from an altitude of 100 to 1,000 miles. The Van Allen belts are zones of intense radiation trapped in the Earth's magnetosphere. The magnetosphere is a region dominated by the Earth's magnetic field that traps charged particles. The magnetosphere begins in the upper atmosphere, where it overlaps the ionosphere, and extends several thousand miles further into space. Geosynchronous transfer orbit is an orbit that originates with a parking orbit (i.e., flight path in which spacecraft go into LEO, circle the globe in a waiting posture and then transfer payloads to final higher orbits) and then reaches apogee (i.e., the point in an orbit that is furthest from the earth) at the Geosynchronous Earth Orbit (GEO). GEO is an

[d] "Amateur rocket activities" are defined in 14 Code of Federal Regulations (CFR) 401.5 as "launch activities conducted at private sites involving rockets powered by a motor or motors having a total impulse of 200,000 pound-seconds or less and a total burning or operating time of less than 15 seconds, and a rocket having a ballistic coefficient-i.e., gross weight in pounds divided by frontal area of rocket vehicle--less than 12 pounds per square inch."

orbit at 22,300 miles altitude that is synchronized with the Earth's rotation. If a satellite in geosynchronous orbit is not at 0 degrees inclination, its ground path describes a figure eight as it travels around the Earth.

This PEIS includes commercial LV launches from existing government launch facilities, commercial launch sites developed at or near government facilities, and launch sites that would require entirely new development and construction. Potential environmental effects of launches from ignition, liftoff and ascent through the atmosphere to orbit, and the disposition of rocket components down range are assessed. The PEIS scope encompasses all activities from lift-off to payload separation. Related activities, including vehicle assembly and payload preparation prior to liftoff, payload functioning during useful life, and payload reentry whether controlled or uncontrolled, are outside the scope of this PEIS. Because the scope is limited to assessment of environmental consequences of launches, no construction activities (e.g., development of new launch sites) are assessed. Construction activities, if they occur, will be addressed in separate site-specific environmental documentation.

The scope of this PEIS does not include site-specific, localized effects. Localized effects and the cumulative impact of these localized effects at an individual launch site can only be appropriately analyzed in the environmental review of a launch site operator. Environmental reviews in support of launch licenses address the environmental impacts associated with issuing a license. Environmental reviews in support of launch operator licenses address the local and cumulative impact of launches from the specific site. Both types of reviews (i.e., launch licenses and launch operator licenses) are expected to tier from this PEIS.

AST has prepared a separate PEIS (Programmatic Environmental Impact Statement for Commercial Reentry Vehicles, May 1992) to assess the impacts of licensing reentry vehicles (RVs). The RV PEIS includes impacts from atmospheric emissions, noise sources, and landing activities. In the future, technologies may be developed by industry and incorporated into LVs that are licensed by AST that combine characteristics of expendable launch vehicles and reusable launch vehicles. Programmatic consideration of the reentry phase for reusable components was included in the May 1992 RV PEIS; consideration of the launch phases, including noise and atmospheric effects, is included in this assessment. Site-specific documentation will address general ground operations and site-specific safety and other environmental issues.

As the designated authority for regulating U.S. commercial space launch activity and the responsible agency for issuing commercial launch licenses, AST is the lead agency for preparation of this PEIS. Consultation with other federal and state agencies was initiated through the scoping process. No other agency has been designated a cooperating or co-lead agency.

1.5. Roadmap to the PEIS

Section 2.0 provides a description of the preferred alternative, the more environmentally-friendly propellant combinations alternative, and the no-action alternative. Section 3.0 describes the existing environment potentially impacted by LV launch operations. Section 4.0 describes potential accident scenarios. Section 5.0 describes the potential environmental impacts and consequences of the preferred alternative. Section 6.0 describes the potential environmental impacts and consequences of the more environmentally-friendly propellant combinations alternative. Section 7.0 describes the potential environmental impacts and consequences of the no action alternative. Section 8.0 describes the potential cumulative impacts of the preferred alternative. Section 9.0 discusses mitigation of the potential environmental impacts of the preferred alternative. Section 10.0 outlines the relationship between short-term use and the long-term effects of the preferred alternative on the environment. The commitment of resources for LV programs is discussed in Section 11.0. Section 12.0 provides a description of the public coordination process, and coordination comments received during scoping. The preparers of the PEIS are listed in Section 13.0. A glossary of terms used in this document is included after Section 13.0. Several appendices provide technical support for impact analyses, regulatory background, and the draft distribution list for the PEIS.

2. ALTERNATIVES

2.1. Introduction

The commercial launch vehicle industry has attempted to promote convenient, affordable access to space, to satisfy the payload lift requirements of the space industry, and to promote commercial development of space. In the past three decades, space has become increasingly important in a broad range of areas including scientific research, communications, and navigation. Technologies such as telecommunications and microgravity crystal growth are making use of space and its unique environment and are being developed for direct application in commercial use. These new technologies, and industry's desire to market them, have created the need for increased commercial space transportation. The demand for access to space cannot be met by the current or foreseeable U.S. military or NASA space vehicles, and so the commercial launch vehicle program is critical to ensure the U.S. remains in the forefront of commercial space development. Furthermore, current U.S. space policy requires that the U.S. government encourage private sector and state and local government investment and participation in the development and improvement of U.S. launch systems and infrastructure.[2]

The primary commercial use for launches is placement of communication satellites in either LEO or GTO. The demand for communication satellites has been steadily growing due to new technologies such as mobile communications services and global positioning systems, as well as direct broadcast systems and remote sensing satellites. Demand for communication satellites arises from U.S.-based companies and foreign initiatives (which can be government or privately sponsored). Although communication satellites are the most frequent payloads at this time, other commercial applications are possible in the future. Sounding rockets carry payloads to an altitude of 1,500 km with recovery of payload possible, and are used to support scientific experiments.

2.2. Preferred Alternative

2.2.1. Description of Action

The preferred alternative for this PEIS is the Commercial Launch Vehicle Licensing Alternative. The categories of LVs under consideration for analysis of environmental impacts under this preferred alternative will encompass the following LV characteristics and launch profiles:

- payload capacity,
- types of propulsion systems, and
- launch platforms -- ground, air, or sea-based.

As detailed above in Section 1.4, launches from both government launch sites and commercial launch sites are included in the preferred alternative. This PEIS considers the effects of commercial LV launches from ignition, liftoff and ascent through the atmosphere to orbit, to payload separation. During ascent through the atmosphere, expended stages and other hardware (e.g., fairings) are jettisoned, usually into oceans; this activity is within this PEIS's scope. In contrast, reusable stages could be returned to Earth via parachute for recovery; impacts of such reentry activities are assessed in AST's 1992 PEIS for Commercial Reentry Vehicles. The remaining events of a launch (e.g., vehicle assembly, payload preparation, payload functioning during useful life, and payload reentry, if applicable) are not addressed by this PEIS.

LVs can place commercial payloads in various orbits around Earth, including Low Earth Orbit elliptical orbits, and geosynchronous transfer orbits. Generally, if a payload is to be placed in GTO it requires an LV with multiple propulsion stages. The orbit in which an LV places its payload depends upon the LV's trajectory (the curve described by an object moving through space), launch location, and payload capacity. Sounding rockets do not place a payload in orbit, but instead return to Earth after a rapid ascent. Total flight time of up to about 20 minutes allows for conducting scientific experiments.

2.2.2. Launch Activity Estimates

AST estimates that the total commercial world-wide launch demand to place payloads in LEO and GTO orbits between 1998-2009 will require 711 launches. As seen in Table 2-1, the total number of U.S. GTO and LEO launches estimated for all types of currently proposed vehicles for this analysis is 436. The criteria under which FAA will grant licenses are described in 49 U.S.C. Subtitle IX, ch. 701-- Commercial Space Launch Activities and supporting regulations. Although these numbers assume a larger U.S. market share than currently anticipated, AST is evaluating an upper bound in case of unforeseen events, such as international LV accidents or new technology requirements, that could dramatically increase the number of LVs launched commercially from the U.S. The launch activity estimates used in this analysis were derived from several sources, as is described below.

TABLE 2-1
TOTAL NUMBER OF U.S. COMMERCIAL SPACE LAUNCHES BY LAUNCH CAPACITY CATEGORY, 1998-2009

	# OF U.S. LAUNCHES
SMALL CAPACITY <2,000 lbs GTO or < 5,000 lbs LEO	173
MEDIUM CAPACITY 2,000-3,999 lbs GTO	73
INTERMEDIATE CAPACITY 4,000-8,999 lbs GTO or >5,000^{+} lbs LEO	102
HIGH CAPACITY 9,000-10,000^{+} lbs GTO	88
TOTAL	436

Note: LVs delivering multiple payloads to orbit are classified under their cumulative payload capacity.

<u>Small Capacity Launch Estimates.</u> U.S. small capacity commercial launches are defined as LVs of less than 2,000 lbs GTO or less than 5,000 lbs LEO, and include estimates for launches of sounding rockets and NASA and DOD-licensed launches (e.g., ultralight-type vehicles). Table 2-2 summarizes the total number of small capacity U.S. commercial space launches for the years 1998-2009 estimated for this analysis. Estimates for these small capacity launches were developed from internal AST estimates.

TABLE 2-2
TOTAL NUMBER OF SMALL CAPACITY U.S. COMMERCIAL SPACE LAUNCHES
FOR THE YEARS 1998-2009

SMALL CAPACITY	**NUMBER OF U.S. LAUNCHES**												
	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**TOTAL**
U.S. Small commercial: < 5,000 lbs LEO or <2,000 lbs GTO*	7	6	7	10	11	14	8	11	14	12	12	13	125
U.S. Sounding Rockets*	2	2	2	2	2	2	2	2	2	2	2	2	24
U.S. NASA/DOD Licensed LVs*	2	2	2	2	2	2	2	2	2	2	2	2	24
TOTAL													**173**

* Source: 6/23/98 AST estimates.

Medium, Intermediate, and High Capacity Launch Estimates. The total number of U.S. medium, intermediate, and high capacity launches used in this analysis, 263, was developed from internal AST estimates. Table 2-3 summarizes the distribution of these launches by year from 1998-2009. Because estimates of the breakdown of these launches into the subcategories of medium, intermediate, and high are not available for the U.S., this analysis uses distributions available from data based on worldwide launches. These distributions are published in the Commercial Space Transportation Advisory Committee (COMSTAC)'s Commercial Spacecraft Mission Model Update (May 1998)[3] and AST's 1998 LEO Commercial Market Projections (May 1998)[4].

Table 3.0 in the COMSTAC report includes launch demand forecasts by year for worldwide launches to GTO. For the period 1998 to 2009, COMSTAC forecasts a demand of 291 GTO launches worldwide. This projection was distributed across the medium (7 percent), intermediate (52 percent), and high (41 percent) capacity categories using the distributions in the COMSTAC report.

The data in the LEO report were used to extrapolate LEO launch vehicle demand in the medium, intermediate, and high LV capacity categories (internal AST estimates were used for the small capacity category, as described above). However, the data in this report were not broken out completely via LV capacity categories, unlike the COMSTAC report. As a result, we had to extrapolate the LV demand information from the payload demand data.

On page 12 of the LEO report, worldwide payload demand for the categories of big LEO, little LEO, broadband LEO, and remote sensing/foreign science payloads is described. Worldwide launch demand estimates are also provided for the entire medium-to-heavy launch capacity category (i.e., 231 worldwide launches were forecast for 1998-2009). This analysis assumed the following: (1) the small capacity category was represented by payloads in the little LEO and remote sensing/foreign science payloads category (and thus were not needed for this estimate of the medium, intermediate, and high capacity demand); (2) the medium capacity category was represented by payloads in the big LEO category; and (3) the intermediate/high capacity category was represented by payloads in the broadband LEO category.

Next, the total number of worldwide medium-to-heavy LEO launches projected per year provided in this report was distributed across the different types of payloads (i.e., medium, intermediate, and high categories). It was assumed that the number of payloads per vehicle would be similar across the capacity categories. For example, in 2001, the LEO report forecasts 18 big LEO payloads and 64 broadband LEO payloads, for a total of 82 medium/intermediate/high payloads. The LEO report also projects 15 medium-to-high capacity launches in 2001. The percent of big LEO payloads (i.e., 18 of 82, or approximately 22 percent), was then applied to the total number of launches (i.e., 22% of 15, or approximately 3 launches) to estimate the total number of medium capacity launches in that year. The 64 broadband payloads were assumed to be associated with the remaining 12 launches, equally distributed across the intermediate and high capacity categories (i.e., 6 intermediate launches and 6 high launches).

In sum, the global number of GTO launches projected for 1998 to 2009 used in this analysis is 291. The global number of medium (100), intermediate (66) and high (66) LEO launches is 232 (note, rounding increased this value by one from the LEO report value). The total number of global LEO launches is 232 medium/intermediate/high launches plus 141 small launches, or 373 worldwide LEO launches. Thus, the distribution of launches worldwide is 44 percent GTO launches (291 of 664), and 56 percent LEO launches (373 of 664) launches.

Finally, the U.S. portion of these worldwide launches was estimated. As stated earlier, the U.S. total number of medium, intermediate, and high capacity launches used in this analysis is 263. This number was multiplied by the global distribution of GTO and LEO launches to result in 115 estimated U.S. GTO launches, and 148 estimated U.S. LEO launches. These numbers were then multiplied by the payload capacity distributions in the COMSTAC report - i.e., medium (7 percent), intermediate (52 percent), and high (41 percent). This yielded 8 medium, 60 intermediate, and 47 high capacity U.S. GTO launches, and 65 medium, 42 intermediate, and 41 high capacity U.S. LEO launches. This results in 73 medium U.S. launches, 102 intermediate U.S. launches, and 88 high U.S. launches out the of the U.S. borders for a total of 263 non-small launches overall. Table 2-3 summarizes the total number of medium, intermediate, and high capacity U.S. commercial space launches for the years 1998-2009.

TABLE 2-3
TOTAL NUMBER OF MEDIUM, INTERMEDIATE, AND HIGH CAPACITY U.S. COMMERCIAL SPACE LAUNCHES FOR THE YEARS 1998-2009

MEDIUM, INTERMEDIATE, AND HIGH CAPACITY	NUMBER OF U.S. LAUNCHES												
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	TOTAL
Total U.S. medium, intermediate, and high capacity launches*	20	16	17	23	34	23	21	22	22	21	21	23	263

* Source: 6/23/98 AST estimates.

2.2.3. Characterization of LV Activities

LV activities for this PEIS are categorized using three different criteria: payload capacity (i.e., small, medium, intermediate, and large), propellant type, and launch platform. Payload capacity refers to the mass an LV can lift into a particular orbit, such as LEO or GTO. Predicted number of launches by payload capacity is detailed in Table 2-4. Propellant types and launch platforms are discussed below.

Propulsion Systems. Existing commercial LVs use one or a combination of more than one of the following propulsion systems: liquid hydrocarbon propellant (e.g., RP1 plus an oxidizer such as LOX); cryogenic propellants (e.g., LOX/LH_2 , where the fuel and oxidizer[e] are maintained at very low temperatures); hypergolic propellants (e.g., hydrazine or nitrogen tetroxide, where the mixing of the hydrazine fuel and the nitrogen tetroxide oxidizer ignites without an initiating energy source), and solid propellant (e.g., poly butadiene acrylonitrile [PBAN] and powdered aluminum). LVs can have one or more stages. Generally, if a payload is to be placed in GTO, current technology requires an LV with multiple propulsion stages. Hybrid propulsion systems are currently under development and could be used for commercial LVs in the future. The hybrid system currently being tested for flight consists of solid propellant with LOX as a liquid oxidizer, giving this system the ability to throttle, shut-off, and restart in mid-flight.

[e] An oxidizer is a substance such as perchlorate, permanganate, peroxide, nitrate, oxide or the like that yields oxygen readily to support the combustion of organic matter, powdered metals, and other flammable material.

TABLE 2-4
U.S. COMMERCIAL SPACE LAUNCH SYSTEMS BY PAYLOAD CAPACITY AND PROPELLANT TYPE

	SOLID PROPELLANTS	**LIQUID PROPELLANTS**			**HYBRID PROPELLANTS**
		Liquid Hydrocarbon	**Hypergolic**	**Cryogenic**	
SMALL CAPACITY <2,000 lbs GTO or < 5,000 lbs LEO	X	X			
MEDIUM CAPACITY 2,000-3,999 lbs GTO	X	X	X		
INTERMEDIATE CAPACITY 4,000-8,999 lbs GTO or 5,000+ lbs LEO	X	X	X	X	Anticipated
HIGH CAPACITY 9,000-11,000+ lbs GTO	X	X	X	X	Anticipated

"X": Propellant currently in use for rocket stage(s).

NOTES: Some LVs with multiple stages use more than one propellant type.
This table does not include payload attitude control system (ACS) propellants.
Vehicles with the ability to reach GTO are classified in this table as GTO vehicles; these vehicles may also be used to reach LEO.

Launch Platforms. LVs can be launched from land, air or sea-based launch platforms. Historically, almost all commercial launches have been from a land-based platform; however new LV designs are expanding commercial launch capability to air and sea. The advantages of launching from an air-or sea-based platform when compared to a fixed land-based platform include: reduced waiting time for a launch slot, ability to place payloads in equatorial or other orbits without the use of a larger LV, minimizing land overflight, minimizing environmental impacts, and possible cost savings. Table 2-5 summarizes current and proposed U.S. launch platforms.

TABLE 2-5
CURRENT U.S. COMMERCIAL SPACE LAUNCH SYSTEMS BY PAYLOAD CAPACITY AND LAUNCH PLATFORM

	LAND	AIR	SEA
SMALL CAPACITY <2,000 lbs GTO or < 5,000 lbs LEO			
MEDIUM CAPACITY 2,000-3,999 lbs GTO			
INTERMEDIATE CAPACITY 4,000-8,999 lbs GTO or >5,000+ lbs LEO			
HIGH CAPACITY 9,000-10,000+ lbs GTO			

Existing vehicles

Under development

No industry proposal at this time

Small Payload Capacity. For this PEIS, a small payload capacity LV is a vehicle that can launch 2,000 pounds or less into GTO or 5,000 pounds or less into LEO. Most of these LVs are propelled by solid rocket motors (SRMs) and can be launched from the ground or the air. AST's 1996 manifest indicates that all of the small capacity launches for that year were from air-based platforms, with the exception of a single suborbital launch from land. The 1997 AST launch manifest states that 25 percent of small capacity launches were launched from the air. It is probable that the percentage of air platform launches will be 50 percent or higher from 1998-2009. It is expected that approximately 173 small launches will occur between 1998-2009.[f] Figures 2-1 and 2-2 illustrate a typical flight sequence for air (Figure 2-1) and land-based (Figure 2-2) launches of vehicles carrying small payloads. Figure 2-3 illustrates a typical sounding rocket flight profile, a graphic portrayal or plot of the flight path of an aeronautical vehicle in the vertical plane. A generic time sequence for flight events is included below the figures.

Medium Payload Capacity. An LV with medium payload capacity can put a 2,000 to 4,000 pound payload into GTO. Currently all LVs with this capacity launch from the ground, however it is conceivable that sea- or air-based launches could occur. For the purposes of the PEIS, it is estimated that 73 medium capacity LVs will be launched between 1998-2009. Most of the current medium LVs have at least two stages, one solid propellant and the other liquid propellant.

[f] The 1996 AST launch manifest also shows one additional small launch in 1998.

There are no hybrids known to be currently under development for this lift capacity. Figure 2-4 illustrates a typical flight profile for a medium or intermediate capacity LV.

Intermediate Payload Capacity. The majority of commercial launches will be LVs with intermediate payload capacity. For the purposes of this PEIS, intermediate LVs are vehicles capable of carrying between 4,000 and 9,000 pounds into GTO or more than 5,000 pounds into LEO. Most intermediate capacity LVs are multi-staged rockets with two liquid stages, or strap-on solids and liquid stages. Multi-staged rockets have two or more rocket units each of which fires after the one before it exhausts its propellant. In the next three to five years, it is likely that there will be an intermediate capacity LV with a hybrid propulsion system. The hybrid propulsion system would consist of a solid propellant (powdered aluminum in a polymer matrix) with a liquid cryogenic oxidizer (liquid oxygen). Thus, hybrid LVs would be expected to emit alumina, but not HCl. Currently all of the intermediate capacity LVs are launched from the ground. No documented plans have been identified to develop intermediate payload launch capacity from the air or sea. However, a reusable vehicle with intermediate payload capacity is under development; the vehicle would consist of two stages, using kerosene and LOX. After a parachute- and air bag-assisted landing, the stages would be reassembled, re-fueled, and reused. This PEIS projects 102 intermediate category launches from 1998-2009. The flight profile in Figure 2-4 also applies for a typical intermediate capacity LV. The jettison of reusable vehicle stages is indicated with a dotted line as an optional approach.

High Payload Capacity. LVs with high payload capacity can lift from 9,000 to 10,000 lbs into GTO. For the purpose of this PEIS, the high capacity category will also include future vehicles that have greater than 10,000 pounds payload capacity. It is likely that a hybrid propulsion system will boost the lift capacity of intermediate and high capacity LVs well past the 10,000 pound payload lift capacity threshold in the next 10 years. High capacity LVs have multiple stages including liquid and solid propulsion systems. The majority are launched from the ground, but future launches could be sea-based. A sea-based launch platform for high capacity vehicles is currently under development. There were no sea-based launches during 1996 or 1997. It is estimated that between 1998-2009 that five percent of the high capacity launches will be from sea-based launch platforms. At this time it is not technically feasible to launch high capacity LVs from the air due to their size, propellant weight, and safety considerations. For the PEIS, the expected number of high capacity commercial launches between 1998-2009 is 88, much lower than intermediate lift capacity LVs. For the high payload capacity LV, Figure 2-5 presents a typical flight profile.

FIGURE 2-1
TYPICAL FLIGHT SEQUENCE FOR AIR-BASED LAUNCHES OF VEHICLES CARRYING SMALL PAYLOADS

Typical Flight Sequence for a Small Capacity Launch Vehicle (Air-based Launch)

Time (Min:Sec)	Event
00:00	Launch
00:05	Stage 1 Ignition
01:16	Stage 1 Burnout/Separation
01:35	Stage II Ignition
01:52	Fairing Separation
02:46	Stage II Burnout
09:54	Stage III Ignition
11:00	Orbit Insertion

FIGURE 2-2
TYPICAL FLIGHT SEQUENCE FOR LAND-BASED LAUNCHES OF VEHICLES CARRYING SMALL PAYLOADS

Typical Flight Sequence for a Small Capacity Launch Vehicle (Ground-based Launch)

Time (Min:Sec)	Event
00:00	Ignition and Liftoff
01:21	Burnout, Separation/Stage 1 Ignition
02:34	Stage 1 Burnout/Separation
02:39	Stage II Ignition
02:42	Fairing Separation
04:00	Stage II Burnout
11:40	Stage II Separation/Stage III Ignition
12:50	Orbit Insertion
13:50	Payload Separation

FIGURE 2-3
TYPICAL FLIGHT PROFILE FOR A SOUNDING ROCKET

Source: National Aeronautics and Space Administration. Draft Supplemental Environmental Impact Statement for Sounding Rocket Program. August 1994, p. 2-54.

FIGURE 2-4
TYPICAL FLIGHT PROFILE FOR A LAND-BASED MEDIUM OR INTERMEDIATE CAPACITY LV

Typical Flight Sequence for a Medium and Intermediate Capacity Launch Vehicle

Time (Min: Sec)	Event
00:00	Main Engine and Initial SRM Ignition
01:06	Initial SRM Jettison/Subsequent SRM Ignition
02:10	Subsequent SRM Jettison
04:25	Main Engine Cutoff
04:38	Stage II Ignition
05:02	Fairing Jettison
21:51	Second Engine Cutoff
23:21	Stage III Ignition
24:48	Stage III Burnout
26:41	Payload Separation

FIGURE 2-5
TYPICAL FLIGHT PROFILE FOR A LAND-BASED HIGH CAPACITY LV

*Note: This schematic only depicts this high capacity vehicle deploying a single payload. However, high capacity vehicles can carry more than one payload.

Typical Flight Sequence for a High Capacity Launch Vehicle

Time (Min: Sec)	Event
00:00	SRM Ignition
01:48	Stage 1 Ignition/SRM Jettison
04:30	Stage II Ignition/Stage 1 Separation
04:40	Payload Fairing Jettison
08:14	Stage II Shutdown
08:30	Orbital Insertion
08:30+	Payload Separation

2.3. Alternatives Considered

2.3.1. Non-Solid Propellant Alternative

AST considered several alternatives to the preferred alternative including the non-solid propellant alternative in which AST would preferentially license only those vehicles that use liquid or hybrid fuels. Under this alternative, no commercial vehicles that use solids would be licensed by AST.
Table 2-4 shows that the majority of commercial vehicles for all payload sizes rely on the use of solids for their propellant systems. Implementing the non-solid propellant alternative would eliminate the majority of commercial launches by existing launch service providers. This alternative is therefore considered to be infeasible and although considered, will not be specifically assessed in the remainder of the document.

2.3.2. More Environmentally-Friendly Vehicles Alternative

Under this alternative, AST would not license any commercial LVs until such time that a new LV is designed that causes no adverse impacts to the environment. This alternative would prevent all current and proposed U.S. commercial LVs from being licensed. Implementing this alternative would prevent U.S. launch service providers from launching any payloads in the foreseeable future. Therefore, all U.S. companies who want to launch satellites will be forced to rely on foreign countries to launch their satellites. This will put additional pressure on foreign markets to keep up with the increased demand. This alternative is not assessed further in the document because it does not fit with the mission of AST and is therefore not considered to be a feasible alternative.

2.3.3. Composite Vehicle Construction Alternative

Under this alternative, AST would preferentially license those vehicles that are constructed of composite materials to make the vehicle lighter and therefore, not require as much fuel to reach orbit. These vehicles do not currently exist and there are no realistic plans to develop them in the near future. Therefore, until U.S. launch service providers research, develop, and test this type of composite vehicle all U.S. companies that want to launch satellites will be forced to rely on foreign countries to launch their satellites. This alternative is not considered to be a feasible option for AST to implement and therefore is not assessed further in the document.

2.3.4. More Environmentally-Friendly Propellant Combinations Alternative

Under this alternative, AST would preferentially license those rockets that produce less harmful tropospheric and stratospheric air emissions of HCl and Al_2O_3. These types of emissions are associated with SRM propellants. Therefore, this alternative would be to preferentially license LVs with no SRMs or combinations of SRMs and liquids. This alternative was retained for detailed study, see Section 2.4.1 below.

2.3.5. No Action Alternative

Under the no action alternative, AST would not issue licenses for commercial LV launches. Therefore, no U.S. launch companies would be able to conduct launch operations. U.S. companies would need to contract the services of foreign launch providers to insert their satellites into orbit. This alternative was retained for detailed study, see Section 2.4.2 below.

2.3.6. Commercial Launch Vehicles Licensing Alternative

This is the preferred alternative under which AST would license commercial launch vehicle launches. Licenses would be issued in accordance with the specifications set out in 49 U.S.C. Subtitle IX, ch. 701 and supporting regulations. Under this alternative, some site-specific NEPA analysis would still be required, prior to issuing launch licenses. This alternative was retained for detailed study, see Section 2.4.3 below.

2.4. Alternatives to be Considered in Detail

Based on a systematic evaluation of the full range of potential alternatives, three alternatives will be carried forward for detailed environmental impact assessment, the more environmentally-friendly propellant combinations alternative, the no action alternative, and the commercial launch vehicles licensing alternative. The more environmentally-friendly propellant alternative will be examined in detail in Section 2.4.1 below. The no action alternative will be examined in detail in Section 2.4.2 below. The commercial launch vehicles licensing alternative will be examined in detail in Section 2.4.3 below.

2.4.1. More Environmentally-Friendly Propellant Combinations Alternative

In its analysis of possible alternatives, AST considered options for preferentially licensing LVs with environmentally friendly attributes, relative to LVs with neutral or more environmentally harmful attributes.

Additional environmental characteristics that AST considered but rejected include:

- <u>Payload capacity</u>. Air emissions from LVs also vary by payload capacity. Lower-capacity LVs tend to use less powerful engine systems and have lower emissions as compared to higher-capacity LVs. Payload capacity is also related to propellant system.

- <u>Noise level</u>. Some LVs produce less harmful noise as perceived by human and/or wildlife receptors relative to other LVs. Perceived noise level may be a function of the vehicle engine system size, noise control measures implemented during launch, and the location and sensitivity of receptors. In general, high capacity vehicles with the largest engines produce the most noise; however, if the launch site is in a very remote area, there may be very few receptors nearby to be affected by the noise.

- <u>Type of launch platform</u>. Some LVs have launch profiles that may result in less environmental effects than other launch profiles. For example, it is possible that a sea-based launch platform may have less environmental effects on some biological resources (e.g., no soil or vegetation impacts) and human populations (e.g., less human noise exposure) than a ground-based launch platform, but more effects on other biological resources (e.g., perhaps a heightened risk of a marine mammal strike). The magnitude and trade-offs of environmental effects produced will be a function of the site-specific characteristics of sensitive biological resources and human populations at the launch sites being considered.

The environmental characteristic that AST considered and determined needed more detailed analysis is:

- Air Emissions. Air emissions from LVs are determined mainly by propellant type. The environmentally harmful chemicals emitted to the atmosphere vary by the type of propellant used. For example, all propellant systems produce CO_2, which is a greenhouse gas. Greenhouse gas emissions in the troposphere and stratosphere are of concern as they contribute to global warming by trapping re-radiated energy in the atmosphere (e.g., water vapor, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrolfluorocarbons, and perfluorinated carbons). Hybrid and LOX-RPI propellant systems produce more CO_2 than solid propellant systems, however, they emit less NOx than systems using hypergolic propellants. Only solid rocket motors (SRMs) produce tropospheric and stratospheric emissions of HCl and Al_2O_3. HCl is a toxic gas that can destroy stratospheric ozone and is defined by the EPA as a Hazardous Air Pollutant. Al_2O_3 is a particulate that can serve as a site for atmospheric reactions depleting ozone. Emissions of HCl and Al_2O_3 are perceived as more significant, immediate environmental threats than the greater amount of CO2 emissions produced by hybrid and LOX-RP1 propellant systems (see Appendix A).

Thus, for this analysis, the alternative option of "More Environmentally-Friendly Propellant Combinations" was defined as consideration of vehicles that produce less harmful tropospheric and stratospheric air emissions of HCl and Al_2O_3. Because these emissions are clearly linked to a single propellant system (i.e., SRMs), an alternative to the preferred alternative is to preferentially license LVs with no SRMs or combinations of SRMs and liquids in the troposphere or stratosphere. LVs powered by SRMs in the troposphere or stratosphere are excluded. While it may be environmentally preferable to limit all SRM usage, this alternative is not feasible because current technology requires a combination of liquids, cryrogenics, and SRM propellants to launch a rocket into geosynchronous orbit. Therefore, preferentially licensing of rocket propellants that do not utilize any SRMs would exclude all larger, three-stage GEO rockets. Furthermore, conclusive data and analysis regarding the specific impacts of emissions from multi-propellant launch vehicles (e.g., liquid and solid combinations) currently do not exist. Because the environmental impacts related to combined emissions of multi-propellant LVs have not been adequately characterized at this time, this analysis relies on existing, available data on emissions from single propellant systems. Ongoing U.S. Air Force, NASA and industry research in this area may alter the future understanding of the cumulative atmospheric impacts of multi-propellant LVs and the relative atmospheric impacts of different types of propellant systems.

Preferentially licensing those rockets that are not solely propelled by SRMs would reduce the total number of launches projected through 2009 to 134; see Table 2-6. The number of launches using liquid, liquid/solid, or hybrid propellant systems was assumed to remain unchanged under this alternative. Thus, the total number of commercial, AST-licensed launches in the U.S.
(i.e., programmatic launches) would decrease substantially under this alternative. It was assumed that the decrease in U.S. commercial launches using only solid propellants would be compensated for by an increase in these launches elsewhere in the world.

TABLE 2-6
TOTAL NUMBER OF U.S. COMMERCIAL SPACE LAUNCHES BY LAUNCH CAPACITY CATEGORY FOR THE YEARS 1998-2009: MORE ENVIRONMENTALLY-FRIENDLY PROPELLANT COMBINATIONS ALTERNATIVE

	NUMBER OF U.S. LAUNCHES: 1998-2009
SMALL CAPACITY <2,000 lbs GTO or < 5,000 lbs LEO	0
MEDIUM CAPACITY 2,000-3,999 lbs GTO	0
INTERMEDIATE CAPACITY 4,000-8,999 lbs GTO or >5,000+ lbs LEO	76
HIGH CAPACITY 9,000-10,000+ lbs GTO	58
TOTAL	**134**

2.4.2. No Action Alternative

Under the no action alternative, AST would not issue licenses for commercial LV launches. Because 49 U.S.C. Subtitle IX, ch. 701 requires commercial launches to be licensed, the U.S. space launch industry would be unable to provide LV launch operations, regardless of launch location. Chapter 701 requires AST to license a launch if the applicant complies and will continue to comply with chapter 701 and implementing regulations. 49 U.S.C. § 70105. One of the purposes of chapter 701 is to provide that the Secretary of Transportation, and therefore AST, pursuant to delegations, oversees and coordinates the conduct of commercial launch and reentry, and issues and transfers licenses authorizing these activities. 40 U.S.C. § 70104 (b) (3). The agency may prevent a launch if it decides that the launch would jeopardize public health and safety, safety of property, or national security, or a foreign policy interest of the United States, 49 U.S.C. § 70104 (c). Not licensing any U.S. commercial launches would not be consistent with the purposes of chapter 701 in this context.

In any event, refusing to license any U.S. commercial launches suffers from other drawbacks as well. It is possible that worldwide demand for commercial LVs would decline if the U.S. were no longer in the commercial market. However, it is more likely that companies in need of launch services would procure these services from another country. It is likely that U.S. telecommunications companies and other U.S. space users would seek other sources to avoid the risk of delaying launch of their satellite systems and falling behind global competition. Similarly, it is reasonable to assume that scientific and microgravity payloads would also seek alternative launch resources. As a result, U.S. satellites and payloads would still be placed in orbit, but on vehicles launched by foreign companies or countries. This, in turn, could also pose a scheduling problem for U.S. payloads because current international agreements limit the number of U.S. commercial payloads that can be flown on foreign launchers. Another scheduling issue could arise with lag time needed to construct additional launch facilities in the alternate countries.

2.4.3. Commercial Launch Vehicles Licensing Alternative

This alternative has been identified as the preferred alternative. Under this alternative AST would issue commercial launch licenses to U.S. companies to conduct launch operations. The licensing process would follow specifications set out in the statute and supporting regulations. Implementing this alternative would allow U.S. commercial launch providers to meet the needs of U.S. companies that want to launch satellites; thus, decreasing the need for U.S. companies to look to foreign launch providers to launch U.S. satellites. This alternative would also leave the opportunity open to U.S. government satellites being launched from commercial LVs.

3. DESCRIPTION OF THE EXISTING ENVIRONMENT

This section discusses the existing environment that could be potentially impacted by an LV launch given the flight profile of an LV and the environment in the immediate vicinity surrounding potential commercial LV launch locations. The discussion begins with a detailed discussion of the Earth's atmosphere, including its regions and boundaries, as related to the flight profiles of the categories of LVs. Then, the baseline noise environment is discussed. Finally, environments near existing and proposed commercial LV launch locations on the Earth's surface are described.

3.1. The Atmosphere

There are four principal layers in the Earth's atmosphere: troposphere, stratosphere, mesosphere, and ionosphere. They are generally defined by temperature, structure, density, composition and degree of ionization. Ionization refers to the electric charge associated with the atmospheric layers, this may be either a positive or a negative charge. The approximate altitude of these layers is provided in Table 3-1.

TABLE 3-1
ALTITUDE RANGE FOR VARIOUS ATMOSPHERIC LAYERS

	Troposphere	Stratosphere	Mesosphere	Ionosphere
Altitude Range	Surface to 10 km	10 to 50 km	50 to 80 km	80 to 1,000 km

3.1.1. Troposphere

The troposphere extends from the Earth's surface to approximately 10 kilometers. It is the turbulent and weather region containing 75% of the total mass of the Earth's atmosphere. It is characterized by decreasing temperature with increasing altitude. The major components of the troposphere are nitrogen (N_2O) (76.9%) and oxygen (O_2) (20.7%). Other components of lesser concentration include water vapor (1.4% in the lower atmosphere), argon (Ar), carbon dioxide (CO_2), nitrous oxide (NO), hydrogen (H_2), xenon (Xe), and ozone (O_3). Certain emissions or toxic contaminants, from both human and natural activities, can cause acute health exposure, degrade ambient air quality, can form acid rain that is deposited on Earth, or can travel to the upper atmosphere to contribute to global warming and ozone depletion. Approximately 10% of the Earth's ozone is in the troposphere.[5] Ozone at the Earth's surface is of great concern because it can directly damage life, including crop production, forest growth, and human health. Ozone is also a key ingredient for smog production.[6]

Ambient air quality in the U.S. in the lower troposphere is regulated through the National Ambient Air Quality Standards (NAAQS) established by the Clean Air Act (CAA). Maximum airborne concentrations are specified for the following criteria pollutants: ozone, carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter of 10 microns or less in diameter (PM_{10}), and lead (Pb). Particulate matter can include small liquid or solid particles. Primary air quality standards provide airborne concentration limits based on human health requirements. Maximum concentrations for CO, NO_2, SO_2, and Pb may only be exceeded one day per year. Ozone and PM_{10} concentrations may exceed the standards an average of once yearly. Table 3-2 provides NAAQS Primary Standards.

TABLE 3-2
NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Unit	Maximum	Average Time Period
Ozone	ppm	0.12	1 hour
CO	ppm	9 35	8 hours 1 hour
NO_2	ppm	0.05	AAM
SO_2	ppm ppm	0.03 0.14	AAM 24 hours
PM_{10}	$\mu g/m^3$	260 75	24 hours AAM
Pb	$\mu g/m^3$	1.5	quarterly

ppm = parts per million
AAM = Annual Arithmetic Mean
$\mu g/m^3$ = micrograms per cubic meter

The Environmental Protection Agency (EPA) specifies whether certain areas attain or meet air quality standards. Nonattainment areas do not meet the NAAQS, whereas attainment areas do meet these air quality standards. EPA addresses mobile sources, such as aircraft, in its assessments of attainment status, but does not address rockets. Aircraft emissions are addressed from the surface to 3,000 feet above ground level.[7] There are many counties in the U.S. that are not in attainment for various pollutants. Ozone nonattainment areas are classified into one of five designations, based on the severity of air pollution. The designations, in order of increasing severity, are: Marginal, Moderate, Serious, Severe, and Extreme. Only the Los Angeles area is in an extreme nonattainment area for ozone. CO nonattainment areas are classified according to the severity of the pollution. Although not covered under NAAQS, rocket emissions, especially potentially large quantities of criteria pollutants, should be considered in any environmental impact analysis.

Under Title V of the Clean Air Act Amendments of 1990, facilities must obtain permits to release regulated air pollutants including criteria pollutants and hazardous air pollutants (HAPs). EPA regulates 188 HAPs, which are chemicals that pose potential health risk to exposed persons. Hydrazine, MMH, UDMH, N_2O_4, and HCl are all EPA-listed HAPs. Therefore, owners and/or operators of sites supporting launches that emit any of these chemicals must obtain a permit from EPA under Title V.

3.1.2. Stratosphere

The stratosphere extends from approximately 10 kilometers to 50 kilometers above the Earth's surface. The stratosphere contains a critical ozone layer for protecting against damage to Earth's biological organisms from ultraviolet sunlight. Most atmospheric ozone (90%) is found in the stratosphere. The highest ozone concentrations are found in the lower stratosphere. Ozone is continually created and destroyed by naturally occurring photochemical processes[8] and its concentration fluctuates seasonally (25%) and annually (1-2%).[9, 10] Ozone is made up of three oxygen atoms and is generated by the action of sunlight to combine an O_2 molecule with an atom of oxygen. Atomic oxygen is produced by photolysis, or the use of radiant energy to produce chemical changes, of molecules of oxygen, nitrogen dioxide, or ozone. Ozone can be depleted by compounds that contain various elements, most notably chlorine, bromine, hydrogen, and nitrogen. Aluminum oxide (particulates), and soot may also provide a reaction surface for the destruction of ozone. NO_2 is also important in the stratosphere; it functions as a major catalytic destroyer at those altitudes.

Unlike the troposphere, the stratosphere is characterized by higher temperatures at the higher altitudes.[11] Ozone contributes to the heat balance of the Earth by absorbing radiation. The stratosphere is also of concern when considering greenhouse gases (e.g., CO_2, H_2O) and associated global warming.

3.1.3. Mesosphere

The mesosphere extends from 50 kilometers to 80 kilometers above the Earth's surface. The upper boundary of the ozone layer occurs at the base of the mesosphere. As a result, the temperature in the mesosphere decreases with altitude. The mesosphere is characterized by varied wind speeds and directions.[12]

3.1.4. Ionosphere

The ionosphere (also called the thermosphere) extends roughly from 80 to 1,000 km (50 to 620 miles) from the surface of the Earth. It is the first part of the Earth's upper atmosphere. The ionosphere is characterized by its high ion (electrically charged particle) and electron density, and is composed of several layers with differing properties.

The major neutral (non-charged) constituents of the ionosphere are atomic oxygen (O), N_2, and O_2, and minor constituents are NO, atomic nitrogen (N), helium (He), Ar, and CO_2. These neutral constituents are strongly influenced by the motions of plasma (ionized gas). This region is a very high vacuum compared to the atmosphere at the Earth's surface, but it still causes some drag on satellites orbiting within it.

The boundaries between the different layers within the ionosphere are indistinct. The lowest region is the E layer, occurring between about 80 and 140 km. The NO^+ ion is the dominant ion in the E layer. The F1 and F2 layers occur in the general area between 140 and 1,000 km, and the dominant ion in these layers is the O^+ ion. The F2 layer is always present, and contains the region of highest electron concentration in the ionosphere (at approximately 300 km). Above the maximum region of electron concentration in the F2 layer, the electron concentration decreases monotonically out to several Earth radii, at which point the Earth's magnetic field and the protonosphere (the outermost portion of the ionosphere) become indistinct from the solar wind or interplanetary plasma.

The different layers of the ionosphere are particularly important to low frequency radio communications. Radiation from the visible spectrum (e.g., aurora) originates in this region. The ionosphere is influenced by solar radiation, variations in the Earth's magnetic field, and the motion of the upper atmosphere. Because of these interactions, the systematic properties of the ionosphere vary greatly with geographic latitude and time (diurnally, seasonally, and over the approximately 11-year solar cycle).[13]

3.2. Noise Sources and Effects

To describe noise and its effects, several terms will be used, as presented below.

Sound. Sound is an energy source produced by vibrating the air or other media. This vibration is made up of many frequencies. The sensitivity of the human ear, or our ability to hear sound, varies with frequency. Humans are most sensitive to sound in the 2,000 to 4,000 hertz (Hz) range. Hertz is a measure of the number of vibrations per second. This will become important when discussing sonic booms and other single event noises, that produce a large amount of their sound energy in the lower frequency range. Sound is measured in decibels (dB) which is a unit for describing the ratio of two powers or intensities, or the ratio of a power to a reference power.

dBA. This is the "A" weighted sound level, a unit used to show the relationship between the interfering effect of a noise frequency, or band of noise frequencies, and a reference power level of –85 dBm. The dB noise scale is a logarithmic scale and therefore the perceived levels increase more sharply than on a linear scale (i.e., a 60dB noise is not twice a loud as a 30dB noise, but is in fact many times as loud.) It is used to characterize noise as heard by the human ear. It accomplishes this by artificially lowering the sound at lower and higher frequencies, where the human ear is less sensitive to sound reception. The dBA is used to assess human reaction to single event noise and is averaged over a 24 hour period to predict community reaction. Single event noise (SEL) is usually reported as maximum dBA (also known as LAMAX). The 24 hour noise level is reported as L_{dn}, which is described below.

psf. Pounds per square foot is a measure of pressure. Sonic booms produce pressure waves that can cause damage. The damage is a function of the pressure produced. Pressure has also been correlated to human response to sonic booms.

L_{dn}. This is the day-night noise level over a 24 hour period. It is reported in dBA, and is used to predict human annoyance and community reaction to unwanted sound (noise). Since humans are typically more sensitive to noise in the evening, the L_{dn} places a 10 dBA penalty on noise produced between the hours of 10 p.m. and 7 a.m.

Noise impacts are very site specific: the closer a receptor is to a noise source, the greater the potential impact. Therefore, the remainder of this section presents a range of scenarios and values regarding noise and its effects.

3.2.1. Existing Noise Environments

Noise is most closely associated with land use. An urban environment is noisier than a suburban environment, and a suburban environment is noisier than a rural environment. Locational and seasonal changes are most readily apparent in rural and wilderness areas where natural noise sources predominate. For example, during the summer season insects can have a substantial effect on noise levels. In comparison, arctic winters are very quiet in the wilderness. Wind can predominate noise levels, especially in forested areas.

The following dBA measurements were recorded at existing launch facilities which encompass various environmental settings:

- remote desert environments[g]: 22-38 dBA[14]
- interstate interchanges (non-urban)[h]: 55-70 dBA[15]
- Marshall Space Flight Center (wooded area with insects dominating the higher reading)[i]: 40-54 dBA[16]
- Vandenberg Air Force Base[j]: 48-67 dBA[17]
- Edwards Air Force Base (with some areas off base at 80 dBA)[k]: 65 - 85 dBA.[18]
- White Sands Missile Range (WSMR)[l]: main post 55 - 65 dBA; property boundary 45-55 dBA; and at nearby San Andreas National Wildlife Refuge 45 dBA.[19]
- Eastern Range[m]: 60-80 dBA.[20]
- Kodiak Launch Complex[n]: 95 dBA approximately 6,250 feet from the center of the pad, decreasing to 70 dBA at a distance of 5.6 to 15 miles from the launch pad.[21]

Table 3-3 presents a broader range of L_{dn} values by land use type.

TABLE 3-3
EXAMPLES OF OUTDOOR DAY-NIGHT AVERAGE SOUND LEVELS AT VARIOUS LOCATIONS

Outdoor Location	L_{dn} in decibels
Apartment next to freeway	88
¾ mile from touchdown at major airport	86
Downtown with some construction activity	79
Urban high density apartment	78
Urban row housing on major avenue	68
Old urban residential area	59
Wooded residential	51
Agricultural crop land	44
Rural residential	39
Wilderness ambient	35

Source: U.S. EPA. Protective Noise Levels: Condensed Version of EPA Levels Document. November 1978.

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[g] Estimate, no other specifics given.
[h] Monitoring data, no other specifics given.
[i] One hour monitoring.
[j] Twenty-four hour monitoring.
[k] Monitoring data, no other specifics given.
[l] Estimate, no other specifics given.
[m] Daytime monitoring
[n] Rocket noise levels from launch of USAF atmospheric interceptor technology (ait) test vehicles.

3.2.2. Noise Sources

This section discusses the potential noise sources associated with commercial LV launches that could pose impacts to nearby sensitive receptors. The generation of sonic booms is an inevitable effect of flight speeds in excess of the speed of sound. The intensity of sonic booms produced by LVs is a function of vehicle size, configuration, and velocity. Noise from LV launches has been described as intense, infrequent, of relatively short duration, and composed predominantly of low frequencies.[22]

Launch Activity. Launch activities produce rocket noise. Rocket noise is produced as the propellant is consumed and exhausted into the atmosphere. Various studies have estimated rocket launch noise at various distances from the source.[23, 24, 25, 26, 27, 28] Although not always specified, these data appear to represent maximum dBA levels. Using atmospheric attenuation, the extrapolation of these various values out to three miles from the pad, results in a noise range of approximately 80 to 120 dBA for all rockets. If one looks at LVs that might be used for commercial launches, the range narrows to approximately 80 to 100 dBA. This seems to be a reasonable estimate as only a limited number of LVs under consideration have a high payload capacity. It has been estimated that most of this noise can be heard for 1 minute.[o][29, 30] It would sound like "distant rumble" in communities surrounding launch areas and could be "noticeably heard" at distances greater than six miles from the launch site.[p][31]

Results of testing at Vandenberg AFB, between 1994 and 1996 confirm the above and yield further insight into this issue. Noise from the Taurus rocket measured an SEL of 108.5 dBA at 7,350 feet from the launch pad. Maximum noise was in the 50 Hz range and lasted from approximately 5 to 15 seconds after launch.[q] The Delta II launch in 1995 was recorded at four monitoring sites. The closest was 1,500 feet from the launch pad and recorded an SEL of 130 dBA. The farthest was 4,000 feet away and recorded an SEL of 122 dBA. At all sites noise above 100 dBA could be heard from approximately 6 to 30 seconds after the launch, with the farthest site receiving the sound approximately 2 seconds after the closest site.[r]

During a 1996 Titan IV launch, measurements were taken in the Channel Islands, 30 to 40 miles from the launch pad. SEL readings were 71 to 74 dBA. Maximum frequency was 10 to 50 Hz and maximum noise could be heard from 5 to 25 seconds after launch. Noise in the 10 to 50 Hz range was approximately 40 dBA higher than noise in our most sensitive range of 2,000 to 4,000 Hz.[s]

Flight Noise. Moving rocket noise is governed by the combustion process, dynamics of the exiting gases, and flight parameters. One modeled case for a generic reentry vehicle indicated a maximum of 65 dBA at approximately four miles from the launch pad.[32] As the rocket ascends, two principles combine to reduce the ground noise levels: (1) separation distance increases; and (2) the air becomes thinner and therefore less capable of transmitting noise.

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[o] Although not specified in the reference, this duration is believed to be experienced by persons located at or near the launch pad.

[p] Although not specified in the document, it is believed that the noise levels at this distance will exceed 70 dBA and "noticeably heard" means increases of 4 dBA or greater.

[q] The Aerospace Corporation. Taurus Launch Sound Levels at Varying Distance from the Launch Pad. August 1994.

[r] The Aerospace Corporation. Delta II Launch Sound Levels at Varying Distance from the Launch Pad: Delta II/Radarsat Launch from VAFB SLC-2W 4 November 1995. May 1996.

[s] The Aerospace Corporation. Channel Islands Noise and Sonic Boom Environmental Measurement Report: Titan IV K-22 Vandenberg AFB Launch 12 May 1996. September 1996.

Sonic Boom. Sonic booms have two potential effects: (1) annoyance and possible health impacts to humans and wildlife, and (2) possible structural damage. Structural damage due to sonic booms is linked to the pressure wave (called overpressure) that is created. Overpressure is the transient pressure, usually expressed in pounds per square foot (psf), exceeding existing atmospheric pressure and manifested in the blast wave from an explosion. Overpressure has also been correlated to human effects. Therefore, in addition to noise measurements, overpressure measurements in psf will be used to help describe impacts.

As a rocket moves through the air, the air is displaced to make room for the rocket and then returns once the rocket passes. In subsonic flight, a pressure wave precedes the rocket and initiates the displacement of air around it. When a rocket exceeds the speed of sound, referred to as Mach 1, the pressure wave can not travel faster than the speed of sound and cannot precede the vehicle, so the parting process is abrupt. As a result, a shock wave is formed at the front of the rocket when the air is displaced around it and possibly at the rear where a trailing shock wave may occur.[33]

The shock wave that results from supersonic flight creates a sonic boom. A sonic boom differs from most other sounds because it is impulsive (similar to a gunshot), there is no warning of its impending occurrence to a potential receptor, and the magnitude of the peak levels is usually higher. Sonic booms from launches occur when vehicles are at supersonic speeds and have pitched over sufficiently for the boom to propagate on the ground. The generation of ascent-related sonic boom from LVs depends on the vehicle geometry and the rocket exhaust plume size and drag. For sub-orbital vehicles, there will also be a sonic boom generated from the descent phase of the instrument package. The geometry of the re-entry of the instrument package affects the development of the sonic boom.[34] For a vehicle flying straight, the maximum sonic boom amplitudes will occur along the flight path and decrease gradually on either side; because of the effects of the atmosphere, there is a distance to the side of the flight path beyond which the sonic booms are not expected to reach the ground. This distance is normally referred to as the lateral cut-off distance.[35] In general, air density will also tend to reduce noise levels reaching the ground as the vehicle ascends, and other parameters such as vehicle shape, trajectory, and atmospheric conditions will effect the formation and propagation of sonic booms.

Atmospheric conditions play a significant role in modeling sonic booms. Space shuttle landings have been estimated to create an overpressure of 2.1 psf and a noise level of 134 dB (unweighted) at the launch pad.[36, 37] Sonic booms over WSMR have been estimated to be 115 dBA, creating 50 to 60 dBA noise levels 5 to 10 miles away from the launch pad. The Atlas II was modeled with results indicating 121 to 134 dB (unweighted) and an over pressure of 0.5 to 2 psf at a distance of approximately 5 miles from the launch pad.[38] Other estimates suggest sonic booms may begin at 1.1 to 1.5 miles from the launch pad[39] and at 21 to 35 miles down range, resulting in 50 to 100 dBA.[40] The modeling of a generic reentry vehicle also reported that the sonic boom may last over a flight distance of 500 miles.[41] A sonic boom due to the overflight of a Titan IV rocket from Vandenberg AFB was measured in the Channel Islands, 30 to 40 miles from the launch pad. At the center of the boom area there was a maximum pressure of 8.4 psf. The boom was also monitored at 12 other locations. Five locations recorded the boom and at a sixth it was heard. Pressure at these locations ranged from a high of 2.4 psf to a qualitatively estimated 0.1 psf.[t]

Sonic booms can also be created when stages fall back to Earth. Variable results have been produced from research in this area, including speculation that noise levels from the descent of stages are

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[t] The Aerospace Corporation. Channel Islands Noise and Sonic Boom Environmental Measurement Report: Titan IV K-22 Vandenberg AFB Launch 12 May 1996. September 1996.

lower than those generated after vehicle take-off, as well as possibly being higher than those generated after take-off.[42] Noise data from the descent of test instrumentation from the USAF Atmospheric Interceptor Technology (ait) sub-sonic vehicle indicate that the maximum sonic boom (generated when the vehicle is at an altitude of approximately 2,400 meters (7,875 feet) and the instrumentation package is about to become subsonic) is about 3.2 psf at the water surface. In comparison, the maximum ascent phase focus boom amplitude at the water surface for the test vehicle is 2.7 psf, with the trailing carpet boom diminishing rapidly as the vehicle gains altitude.[43]

Because launches occur over water, underwater sonic boom propagation must also be considered as a potential noise impact from LVs. Research in this area indicates that the interaction between sonic boom waves with a surface wave train can profoundly influence the underwater propagation and noise penetrating power of the boom. In addition, sonic boom impacts are expected to be more severe in relatively shallow coastal water as compared to in the open sea, as a result of the amplification influence of the ocean floor. Furthermore, it appears that sonic boom noise underwater caused by an LV penetrates further and is more intense compared to supersonic aircraft overflight. Data from the Apollo 17 mission indicate that a rocket plume can generate a sea-level signature length that may exceed two kilometers. Thus, these types of booms may represent a threat of physical and physiological impairment to marine mammals in the vicinity of the water surface, particularly if these mammals occur in the relatively restricted impact zone of the boom. In this impact zone, sonic boom shock strengths may reach 4 to 8 psf.[44]

Noise data from the USAF ait sub-sonic vehicle indicate that the ascent sonic boom for this vehicle, which has an overpressure of 2.7 psf, generates an underwater noise level of approximately 160 dBA for 200 milliseconds. This noise level will attenuate approximately 10 percent (i.e., to 16 dBA) at 100 meters below the ocean surface, and will be spread over only a limited area. The descent sonic boom from the instrument package returned from this vehicle generates an overpressure of 3.2 psf at the water surface for 200 milliseconds, and affects only an extremely small column of ocean.[45]

Accidents. There is very little information regarding noise levels during accidents, as most efforts to date have focused on launch noise. However, an explosion of an LV will produce significantly higher noise levels than those produced during normal operations. The U.S. Air Force predicted a noise level of 200 dBA and an overpressure of 4,000 psf at a distance of 100 feet for a Titan IV/Centaur vehicle. However, an exploding Titan IV should not be considered a bounding scenario, because the Titan IV core vehicle uses hypergolic propellants. In a failure, hypergolic propellants deflagrate, instead of detonate, which produces less overpressure than an LV employing LOX/RP-1 or LOX/LH2. Thus, an accident involving a larger LV such as a Titan IV may produce less noise than a smaller LV, such as an Atlas or Delta. Preliminary analysis of the noise effects of the January 17, 1997 Delta II LV accident and failure indicates that there were no discernible effects on the scrub jay population and that the overall population of Southeastern beach mice actually increased in areas affected by the explosion.[46]

3.3. United States LV Launch Environments (Earth's Surface)

The primary location of activity related to an LV launch is the atmosphere, thus, baseline atmospheric conditions have been detailed in Section 3.1. However, the Earth's surface will be affected by LV launches. This section discusses in broad terms the environmental characteristics of ecosystems representing commercial LV launch locations throughout the U.S. Six different types of environments are characterized. They include Mid-Atlantic Coastal, Southeastern Atlantic Coastal, Southwestern Desert-Arid, South Central California Pacific Coastal, Subarctic Pacific, and Sea-Launch environments. The purpose of including this discussion is to provide generic environmental characteristics against which impacts can be assessed in Section 5. The information below, however, does not purport to address all site-specific launch issues. Any required site-specific environmental documentation would be developed as needed. For example, the presence of threatened and endangered species is a highly site-specific determination, and a discussion of such species is not appropriate for this PEIS. However, other types of environmental characteristics can be meaningfully discussed for a local ecosystem. For example, the impacts of the presence or absence of wetlands and the types of surface water in the vicinity of potential launch locations. Wetlands, swamps, marshes, and bogs are described as including hydric soil conditions, and the plant species that survive in water saturated soil for extended periods of time. In addition, local atmospheric information, such as wind speed, temperature, and annual precipitation, is included to complement and complete the general characterization of the stratosphere presented in Section 3.1.1. To complete the discussion of the Earth's surface, subsection 3.3.5 provides an overview of the marine mammals in the Atlantic and Pacific Oceans for consideration of potential impacts from jettisoned LV materials (e.g., SRMs, stages, payload fairings).

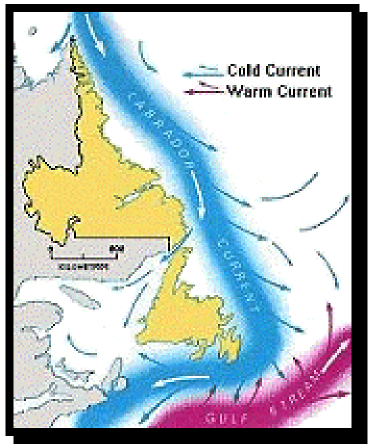
In addition to complying with all federal regulations, launch sites in the continental United States, within the boundary of a State, will need to comply with applicable state laws regarding their proposed facilities and operations. This is particularly true in cases where federal law concedes jurisdiction to State laws and regulations. Further analysis will be done during review of specific launch application technical data and site-specific environmental documentation.

3.3.1. Local Climate/Atmosphere

Climatological and meteorological information is required in the analysis of the environmental effects of launch operations. This information supports predictions of the general dispersion of atmospheric pollutants that may be released by licensed commercial LVs as a result of the preferred alternative. Thus, this section examines generalized local climatic and atmospheric environments. However, the scope of this PEIS does not examine the specific, local environments of launch activities. Analysis of the Clean Air Act and State Implementation Plans, including the determination as to whether the federal action is a de minimus action, will be addressed in site-specific environmental documentation.

Mid-Atlantic Coastal Environment. This climatic region is known as the humid continental warm summer climate zone. Climate is affected by the Atlantic Ocean, and the air current known as the Labrador Current (which pushes the Gulf Stream off shore) (Figure 3-1).

Figure 3-1
Labrador Current



In winter, the climate is dominated by polar continental air masses, and in summer, by tropical maritime air masses. Four distinct seasons have characteristic precipitation and temperatures. Winter is usually wet with low temperatures. Spring is also wet, although temperatures are higher. Summer is hot and humid with many thunderstorms. Autumn has slightly decreased temperatures and strong frontal systems with rain and sustained winds. The annual average precipitation is 93 cm (36.8 in), and the annual average temperature is 17°C (56°F). Winds prevail from the south with greatest speeds in February and March.

Severe weather conditions occur with hurricanes, northeasters, and thunderstorms. These result in high winds, heavy rainfalls, and reduced visibility. Hurricanes most often occur from August through October, while northeasters develop frequently in the winter. Thunderstorms are common during the summer.[47]

Southeastern Atlantic Coastal Environment. The climate in the southeastern U.S. coastal environment is subtropical, characterized by short mild, winters and long hot, humid summers. The average temperature is 21.7°C (71°F). Annual precipitation ranges from 114 cm (44.9 in) to 127 cm (50 in). Rainfall distribution is seasonal, with a wet season occurring from May through October. This area has the highest number of thunderstorms in the U.S., and one of the highest frequencies of occurrence in the world during the summer. Freezing conditions in this climate are rare. Close to the coast, temperatures are moderated by the Atlantic Ocean.

The humidity in this region is highly variable. Summer humidity is typically between 70 and 90 percent. During the non-summer months, the relative humidity is high in the morning (e.g., averaging 90 percent), but drops to between 55 and 65 percent by noon.

Wind speed and direction are variable and correlate with the seasonal meteorological conditions. Winds during the summer are predominantly from the south and southeast, becoming more easterly in the fall. During the winter, winds are typically from the north and northwest. Uneven solar heating of land and water during the summer causes a sea breeze (from ocean to land) during the day and a land breeze (from land to ocean) at night. Inversions are uncommon, occurring approximately two percent of the time.[48]

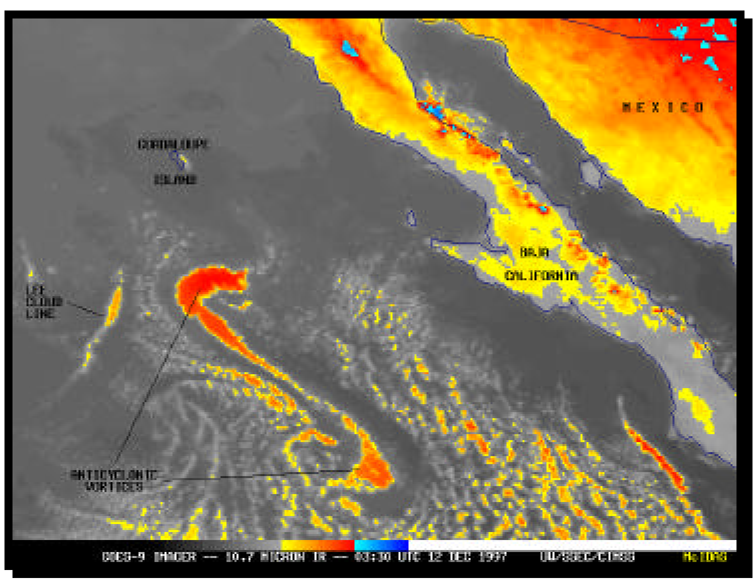
Southwestern Desert-Arid Environment. The southwestern desert arid environment is characterized by relatively mild winters with hot summers. Monthly average temperatures are 7°C (44°F) in January and 32°C (90°F) in July. Average annual rainfall is 23 cm (9 in) at higher elevations and 15 cm (6 in) at lower elevations, with about half the total occurring during July and August due to local thunderstorms.[49] Lightning strikes are a common occurrence. In 1991, for example, an area typifying this environment was subjected to up to 13 lightning strikes per square mile.[50] Most common wind directions are south and southwest, and the strongest winds occur in the late winter and spring. At higher elevations, the average annual wind speed is 10 miles per hour.

South Central California Pacific Coastal Environment. The climate in this environment type is Mediterranean, characterized by warm, dry weather from May to November and cool, wet weather from December to April. The Pacific Ocean has a moderating influence on weather patterns.

The average annual temperature is around 12.8°C (55°F), and the mean annual relative humidity is 77 percent. The average precipitation is 32.3 cm (12.7 in) per year. More than 90 percent of the region's precipitation falls between November and April. Coastal fog and low clouds are common in the morning hours, especially during the summer months when atmospheric inversion conditions intensify.

Wind directions and speeds vary with proximity to the coast, topographic characteristics, and season. Santa Ana winds, resulting from inland high pressure cells that cause warm, dry northeasterly winds to descend down the mountain slopes to the Pacific Coast, can interrupt the normal Mediterranean climate patterns for several hours to several days. (See Figure 3-2) The Santa Ana winds most commonly occur during the fall and winter months. During these periods, relative humidity in the region decrease to less than 10 percent, while temperatures increase accordingly.

Figure 3-2
Santa Ana Winds off the Western United States



The average maximum mixing height (which indicates the upper limit of the atmospheric region where pollutants and emissions tend to remain) ranges from approximately 900 m (2,950 ft) above sea level in July to 1,350 m (4,430 ft) above sea level in November. The mixing height is controlled by the location in the atmosphere of the first layer of air that is warmer than the air below. In this region, the mixing height tends to increase with winds originating from the north and west, and tends to decrease with winds from the east. Higher mixing heights facilitate dispersion of trapped air pollutants.

Subarctic Pacific Environment. The climate in this environment type is Maritime. Weather is affected by cool, humid air masses from the ocean. Long, mild winters last from November through March, with snowfalls occurring December through February. Average daily temperatures during the winter are -1°C (30°F). Average wind speeds are 5.4 meters per second (12 miles per hour). The fall months of September and October have minimal rain and snow with temperatures generally in the 4 to 10°C (40 to 50°F) range. Average wind speeds are 4.5 meters per second (10 miles per hour). The summer months are cool, humid, and windy. Precipitation occurs during half of the months and the sky cover is generally overcast. Average daily high temperatures reach 15.6°C (60°F), but vary greatly depending on the winds. The spring months of April and May are characterized by precipitation on half of the days in each month. An average snowfall during this spring season is 20 to 33 centimeters (8 to 13 inches).

Hazardous weather conditions occur with heavy fog, large snowfalls, and high winds. Heavy fog with visibility of a quarter of a mile or less usually occurs twelve times a year. The large snowfalls in December through February range from 100 to 110 centimeters (40 to 45 inches). High winds occur throughout the year. Monthly peak wind gusts range from 16 meters per second (35 miles per hour) in June to 37 meters per second (83 miles per hour) in December.[51]

Sea Environment. Launch facilities may include several parts; a mobile floating launch pad which could be partially submerged for stability during the launch and an assembly, command ship from which the launch could be controlled and facilities on board to house the workers during the launch activities, and home port facilities where LV and payload can be integrated and maintenance and testing operations can be conducted. A sea-launch environment might consist of a circular area with a radius of 5 kilometers, centered at the launch pad. The sea-launch environment would exist at certain points in time, for example when the launch pad is in a pre-approved geographical region, when the launch pad is in the semi-submerged configuration, and from the time the assembly command ship pulls up to the launch pad to start checkout until the time the assembly command ship pulls away from the launch pad after launch activities are complete.[52]

The typical climate of an island in the equatorial zone near where sea launches might take place has a temperature range between 18.9°C (66°F) to 33.9°C (93°F). Annual rainfall is around 63.2 cm (24.9 in), and the annual number of days with rainfall is approximately 47.3 days. An approximate number of days per year with thunderstorms is 0.6 days. The annual percent frequency of wind speed greater than or equal to 8.8 m/sec (17 knots) is 1.7 percent of the time, with no winds reported over 14.1 m/sec (28 knots).

Ocean currents, winds, and weather patterns are closely linked, especially along the equator in the Pacific. Surface waters cooler than 28°C normally dominate the equatorial ocean and the Pacific Coast of South America.[53] The equatorial Pacific Ocean is a complex environment in terms of its oceanographic biogeochemical processes. This unique ecosystem is characterized by complex ocean-atmosphere interactions and a physically dynamic oceanic circulation pattern.[54] An important process affecting conditions in this region of the Pacific Ocean is the El Niño phenomenon; every three to five years, this cyclical pattern of ocean and atmospheric conditions changes dramatically. (See Figure 3-3) Warm waters occur along the equator and west coast of South America, oceanic nutrient concentrations increase, wind patterns shift, and the effects are felt over much of the Earth. Conversely, tropical instability waves (westward propagating waves along the equator) produce effects lowering sea surface temperatures and increasing nutrient concentrations.

Figure 3-3
El Nino Process

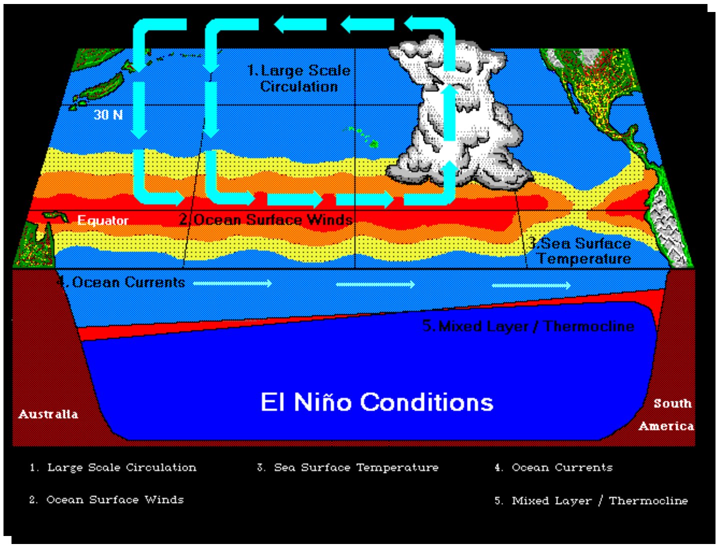
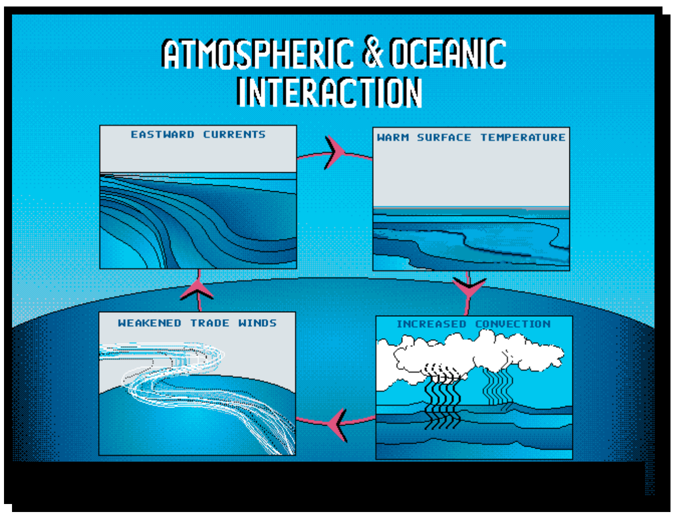


Figure 3-4
El Nino Atmospheric and Oceanic Interaction



3.3.2. Local Land Resources

No land resources would be involved in LV launches from a sea-based launch platform. Generic characteristics of the local land resources of the other environments are detailed below.

<u>Mid-Atlantic Coastal Environment.</u> Topography in the Mid-Atlantic coastal region is generally flat with no extreme deviations. There are numerous inlets, marshes, bays, creeks, and tidal estuaries. The region is characterized by frequent flooding from storms. The area is located within the Atlantic Coastal Plain physiographic province. Soils are generally very level, acidic, have low natural fertility, and are high

in organic content which results in a highly leached condition, (i.e., soluble particles have been removed by the percolation of water).[55]

Southeastern Atlantic Coastal Environment. Topography in this region tends to be very flat. Barrier islands (similar to an offshore bar except they have multiple ridges) areas of vegetation, and swampy terraces extending towards the lagoon, are common along the Atlantic coast. Native soils tend to be highly permeable, fine-grained sediments typical of beach and dune deposits.[56] There is considerable heterogeneity in soil conditions; two major distinct groups are saline soils and non-saline soils.[57]

Southwestern Desert-Arid Environment. Topography in this region includes both desert and mountainous terrain. There are north-south trending mountain ranges with intervening valleys. The region has a history of faulting and volcanic activity. The geology includes sedimentary, granitic and volcanic rocks.[58]

There are many soil types, within this environment, including rock outcrops. With the exception of Marconi soil and some clay, soils generally are well drained, and are composed of gravels, sands, and sandy and loamy silts and clays. Soils are coarse-grained near the mountain fronts and fine-grained in the valleys. They have a high salinity in the valleys. Organic matter, or matter derived from living organisms, in these soils is low, generally below one percent. There are sand dunes scattered throughout the area creating a potential for blowing soil from wind erosion.

South Central Pacific Coastal Environment. Topography in this region varies greatly, particularly close to the coast, which may range from very rocky, steep cliffs to gradual slopes and flats. Intermittent drainages (e.g., major or minor canyons) are common. East-west chains of islands - mountainous outcrops in the Pacific Ocean - can be found off the coast.

This environment contains a complex and varied geology that gives rise to an equally complex pattern of topography and soils. Oil and gas are the dominant geologic resources, and have been extracted from both onshore wells and offshore platforms. The entire south central Pacific coast is seismically active.

Subarctic Pacific Environment. Topography in this region varies greatly, ranging from mountains and hills to flat, low lying areas. These areas are characterized by seismic activity, flooding, and landslides. Soils in this type of environment vary, but are usually moist due to the precipitation. In areas where the large amounts of precipitation result in water tables at or near the surface, the soils have a high organic matter content, which produces a relatively high cation exchange capacity (sum of exchangable cations that a soil or other material can absorb at a specific pH). This property allows soils to offer resistance and be strongly buffered against changes in pH.[59]

3.3.3. Local Water Resources

Surface and groundwater resources that may exist in the vicinity of proposed or currently licensed commercial launch sites are discussed in the following subsections.

Mid-Atlantic Coastal Environment. Surface waters in this environment are saline to brackish (having salinity values ranging from approximately 0.50 to 17.0 parts per thousand), and tidally influenced due to their coastal location. Most water-bearing groundwater formations consist of sedimentary units, ranging in age from Cretaceous to Quaternary. Major aquifers (subsurface zones that yield important amounts of water to wells) are recharged by surface waters or infiltration of precipitation. Groundwater quality is generally good, although moderately hard, with little or no fluoride present. Within the tidal areas, there is brackish water due to saltwater intrusion. There are local iron and nitrate problems. The sea level is expected to rise due to the combined effects of land subsidence and fluctuations in global temperatures. A common floodplain (smooth valley floor adjacent to and formed by alluviating rivers, which are subject to overflow) protection measure in this region is the construction of seawalls to protect the shoreline from erosion. Damage from tidal floods depends on the topography, the rate of rise of floodwater, depth and duration of flooding, exposure to wave action, and the extent of development in the floodplain.[60]

Southeastern Atlantic Coastal Environment. Typical surface water bodies are a mix of shallow estuarine lagoons and major inland water bodies (e.g., large lagoons and rivers). These surface water bodies are used for a range of activities, including recreation, propagation, and management of fish and wildlife, and may be designated as aquatic preserves, Estuaries of National Significance, and/or Outstanding Florida Waters.

Surficial, unconfined aquifer systems exist in upper unconsolidated sediments. These surficial aquifer systems are recharged by precipitation, and can produce good quality water but are very susceptible to contamination. The Floridan aquifer is located beneath confining units below surficial aquifer systems and is the primary drinking water source for the majority of Florida residents. However, in the mid-southeastern coastal region of the state the Floridan is highly mineralized and is generally unsuitable for domestic, industrial, or agricultural use.[61]

Southwestern Desert-Arid Environment. Most desert environments have scarce amounts of surface water except selected areas where springs are common. Springs are the only source of perennial surface water. Ephemeral surface water is derived from nearby mountains and contributes to surface dirt tanks and transient ponds in the water courses. Heavy rain on the packed desert floor runs off rapidly or infiltrates into the dry soil. In floodplain areas, the water runs off less rapidly, but still does not stand or pond. On flats, rainwater may stand and cause flooding.[62]

Aquifer systems underlying the region have varying depths, water levels and areas of confinement. Recharge to aquifers occurs in areas immediately adjacent to major mountain ranges. Some aquifer recharge occurs from storm-water discharge through canyons and arroyos.

South Central Pacific Coastal Environment. The Western Santa Ynez Mountains receive an average annual precipitation of about 41 cm (16 in) per year, with a runoff rate of two to three inches per year. Local drainages may discharge directly into the Pacific Ocean. The flow rates associated with these drainages can be highly variable; many channel water only during storm events. Intense storm episodes produce high intermittent yields due to the relatively steep topography of the area. Some drainages in the area may be spring fed, although ground percolation frequently traps the water flow before it reaches the ocean.

Streams tend to be high in hardness, alkalinity, and specific conductance, but low in acidity, chemical oxidation demand, and total organic carbon. The alkalinity refers to the streams having excess hydroxide ions in solution. These streams also in general have high levels of certain elements such as calcium, iron, magnesium, and sodium.

The underlying rock formation in this region supports a minimal amount of groundwater in the fracture zones. Lower members of the formation contain greater amounts of water than the upper levels.

Subarctic Environment. The subarctic environment typically has riverine, estuarine, and marine systems. The general types of water environments are freshwater streams and lakes, and salt-water influenced lagoons.[63]

3.3.4. Local Biological Resources

The following subsections consider local flora and fauna near existing and proposed commercial launch sites.

Mid-Atlantic Coastal Environment. Wetlands in this region are classified as tidal or non-tidal. The three predominant wetland systems are marine wetlands, estuarine wetlands (wetlands that are continuously submerged or are by turns exposed and flooded by tides), and palustrine wetlands (these wetlands can be nontidal and not vegetated, or have small amounts of woody vegetation). All marine and estuarine wetlands, as well as some palustrine wetlands, are considered tidal wetlands. Non-tidal wetlands can include riverine, lacustrine, and palustrine wetlands. Lacustrine wetlands are situated in topographic depressions surrounding lakes or pooled rivers.

Tidal wetlands include vegetated wetlands such as swamps, marshes, and bogs, as well as non-vegetated wetlands such as beaches and tidal flats. Vegetated tidal wetlands provide wildlife habitat values such as nesting grounds for many species of migratory waterfowl, water birds, and songbirds. These wetlands provide nourishment for oysters, clams, scallops, crab larvae, and newborn fish by providing detritus. The vegetation can absorb wave energy, filter water, and prevent erosion. Typical vegetation includes the saltmarsh cordgrass, salt meadow cordgrass, cattail marshes, black needlerush, saltwort, and reedgrass.[64]

Non-tidal wetlands support vegetation adapted for life in saturated soil conditions (hydrophytic vegetation). These wetlands also provide wildlife habitat, attenuate floodwater, and provide erosion control. Non-tidal wetlands are classified according to their vegetation. Forested wetlands include swamps dominated by trees over 20 feet in height, such as the red maple, river birch, and ashes. Scrub shrub wetlands include tree shrub swamps dominated by trees less than 20 feet in height, such as the alder, buttonwood, and spicebush. Emergent wetlands are marshes with common vegetation being cattails, sedges, and rushes. Aquatic bed wetlands are dominated by plants that grow on or below the surface of the water, such as spatterdock and pickerelweed.[65]

The Mid-Atlantic coastal region contains barrier islands, which are often considered wetland resources. They are narrow land forms consisting of unconsolidated and shifting sand. These islands contain coastal primary sand dunes and swales, which serve as barriers against flooding and erosion caused by coastal storms. The dunes are dominated by northern bayberry, wax myrtle, groundsel-tree, and reeds. Species in the dune system include seabeach orach, common saltwort, sea rocket, and seaside goldenrod. Where there is intense wave action, phytoplankton, macroalgae, and eelgrass are prevalent.

In addition to the dunes, barrier islands contain beaches, maritime forests, and marshes. The maritime forests typically have loblolly pine, cherry trees, northern bayberry, and wax myrtle. Thickets also have clusters of northern bayberry and wax myrtle, as well as dense poison ivy and greenbriar.[66] Barrier island marshes are dominated by saltmarsh cordgrass.[67] The marshes contain many species of marine and bird life, as well as a variety of invertebrates, such as grasshoppers and planthoppers. There are a number of parasitic flies, wasps, spiders, and mosquitoes.[68] Calico crabs, sand shrimp, moon jelly, and coffee bean snails are common in this environment.

Fish species in this Mid-Atlantic coastal region vary depending on changes in inlets and channels, salinity, tide, and temperature changes. Common species include the northern pipefish and the bay anchovy. Others are the sandbar shark, smooth dogfish, spot, and flounder.[69] Amphibians and reptiles characteristic to this region are the fowler's toad, green tree frog, black rat snake, box turtle, and diamondback terrapin.

Shorebirds include the sanderling, red knot, dunlin, willet, terns, and gulls. Sparrows, red-winged blackbirds, fish crows and mourning doves are also common. Mockingbirds, robins and starlings are prevalent throughout the year.

Mammals found in the Mid-Atlantic coastal region include the white-tailed deer, opossum, raccoon, red fox, meadow vole, and grey squirrel. Shrews, moles, rabbits, and bats are also common. The waters are also inhabited by whales, dolphins, and porpoises.[70]

<u>Southeastern Atlantic Coastal Environment.</u> Ecological resources in the southeastern Atlantic coastal area are influenced by the Atlantic Ocean on the east. Vegetation communities and related wildlife habitats are representative of barrier island and coastal resources. Major communities include beach, coastal strand and dunes, coastal scrub, lagoons, brackish marsh, and freshwater systems in the forms of canals and borrow pits. Coastal hammocks and pine flatwoods may also be found. In terms of aquatic biota, the region is a transition between temperate and subtropical forms.[71]

Wetland types found in this region include freshwater ponds and canals, brackish impoundments, tidal lagoons, bays, rivers, vegetated marshes, and mangrove swamps. These wetlands provide resources for a vast assemblage of marine organisms, waterfowl, and terrestrial wildlife. For example, fish living in the marsh habitat include the gar, killifish, mosquito fish, and top minnow; amphibians include the leopard frog; and reptiles include the box turtle, various species of snakes, and alligators. Mammals living in the marsh habitat include different species of rats and mice, raccoons, river otters, muskrats, and deer. Wetland resources in this area are managed by controlling water levels in impoundments, stocking fish in freshwater bodies, and legally protecting many wildlife species as well as the wetland habitat itself.[72]

This region is one of the most biologically diverse coastal ecosystems in the continental U.S., containing a large number of federally protected species.[73]

Typical plant communities include coastal dune, coastal strand, freshwater marsh, freshwater swamp, and developed areas dominated by terrestrial grasses and weeds. Sea grasses are an important component of the aquatic environment.

There is a wide variety of mammals, birds and reptiles in this environment type. The range of mammals includes several species of whales, as well as manatees. Various types of warblers, jays, falcons, woodpeckers, and eagles have habitats in the area as well. Reptiles include the American alligator, as well as numerous species of turtles and snakes.[74]

Southwestern Desert-Arid Environment. From a biogeographic perspective, the southwestern desert area encompasses three major vegetation types. In order of dominance,[75] these are semidesert grassland, plains-mesa sand scrub, and desert scrub. In species composition, these three vegetation types correspond to the desert scrub biotic community and the semidesert grassland biotic community.[76] Grassland habitat merges with desert scrub, creating a complex landscape mosaic. Major vegetation in the desert scrub area includes a combination of woody and herbaceous shrubs such as the creosote bush, shadscale, winterfat, and white bursage. Plains-mesa sand scrub separates semidesert grassland and desert scrub vegetation. The desert scrub vegetation is divided into broadleaf evergreen and broadleaf deciduous types. Flora in this region include sunflowers and buckwheats. There are no wetland types in this environment, however, springs support wetland type vegetation, such as cattail, sedges, and rushes.

The majority of the arthropod species are insects such as ants, termites, and darkling beetles. Common birds are the raven, red-tailed hawk, scrub jay, and black-throated sparrow. Other species that can be found in this region include coyotes, bobcats, speckled rattlesnakes, desert woodrat, and mule deer.[77]

South Central Pacific Coastal Environment. The south central Pacific coastal environment represents a transition zone between the cool, moist conditions of northern California and the semi-desert conditions of southern California. Consequently, many plant species, as well as plant communities, reach their northern and southern limits in this area. Plant communities of particular interest include tanbark oak forest, bishop pine forest, Burton Mesa chaparral, coastal dune scrub, and a variety of wetland types.

Typical vegetation communities include central coastal scrub, coastal sage scrub, coastal dune scrub, grassland, and chaparral. These communities are adapted to periodic burning, and many plant species re-sprout readily after fire. Where disturbances are frequent and intense, ruderal and exotic species replace the native vegetation. Many local canyons support riparian woodlands.

Many species commonly found in coastal sage scrub vegetation environments include deer, badger, coyote, desert cottontail rabbit, turkey, vulture, red-tailed hawk, American kestrel, white-tailed kite, and northern harrier. Other bird species that may be found include raptors, loggerhead shrike, rufous-sided towhee, rufous-crowned sparrows, Bell's sage sparrow, and burrowing owls. Turtles, pelicans, lizards, frogs, sea otters, and harbor seals also have habitats in this area.[78]

The coastline of this region is occupied by several species of seabirds, marine mammals, and other species of interest. Harbor seals, protected under the Marine Mammal Protection Act, use the beaches as haulout and pupping areas. Southern sea otters also feed in the offshore kelp beds and occasionally come ashore. Peregrine falcons nest on the rocky cliffs. Western gulls, brown pelicans, pigeon guillemots, pelagic cormorants, rhinoceros auklets, black oystercatchers, and Brandt's cormorants use the rocky outcrops for roosting or nesting purposes.

Subarctic Environment. The major plant life associated with this region includes forests, shrublands, meadows, and wetlands. A common type of forest is the spruce forest. The shrublands include the closed alder and mixed alder-willow. Typical types of meadow are the low shrub-forb, the willow-hairgrass-mixed forb, the mixed dwarf shrub-graminoid, and lupine meadow.

There are typically non-vegetated and vegetated wetlands. Permanently flooded wetlands have no vegetation or only rooted vascular aquatic vegetation. Vegetated wetlands include semi-permanently flooded areas, saturated emergent wetlands, and marshes. Semi-permanently flooded areas have sandy substrates with less than 30 percent vegetated cover. Saturated emergent meadow wetlands usually have mineral soils with only sedge-forb and sedge-forb moss. Emergent sedge marshes exhibit standing water throughout the growing season. Other vegetated wetlands include saturated tall shrub thickets and dwarf shrub moss with 70 percent or greater coverage of broad-leaved deciduous shrubs.

The habitats in this environment are generally not high quality due to the harsh conditions. Typical bird species in the water habitats include loons, grebes, dabbling and harlequin ducks, gulls, and kingfishers. In the forests, species include varied thrushes, goshawks, golden-crowned kinglets, and boreal chickadees. Wetland bird species include common snipe, mew gulls, terns, and sparrows. Other common bird species are mallards, gulls, ravens, and falcons.[79]

Mammals in this environment include the little brown bat, red squirrel, tundra vole, red fox, black-tailed deer, brown bear, beaver, snowshoe hare, mountain goat, short-tailed weasel, and muskrat. There are various freshwater and anadromous fish.

Marine birds include terns, puffins, gulls, and cormorants. Common marine mammals include cetaceans, harbor seals, sea otters, and whales. Marine fish include flounder, sole, pollock, skate, cod, and halibut. Other common marine organisms include crabs, scallops, octopus, shrimp, clams, jellyfish, sea urchins and mussels.[80]

Sea Environment. The most prevalent biologic organism in the deep ocean environment are tiny phytoplankton. Phytoplankton represent most of the ocean's organic material and are produced in open-ocean waters. Most major fisheries, on the other hand, are located in coastal waters, particularly in upwelling areas. Micro-phytoplankton productivity is an important measure of the oceans' food supplies. Also called primary productivity, these rates largely regulate fishery cycles and may be significant in the global carbon cycle. In general, the equatorial ocean zone is characterized by a large number of species, large biomass, and substantial east-west variability.

Open-ocean food webs are typically long, involving many energy transfers. Only the smallest phytoplankton grow in the nutrient-poor open-ocean waters, and these in turn are consumed by very small herbivores. These tiny herbivore animals are preyed on by animals in the one-millimeter size range, and they, in turn, by secondary carnivores that are about one centimeter long. In many cases, one or two larger invertebrate animals or fishes form additional links in the open-ocean food chain before it reaches a carnivore, such as mackerel or tuna.[81]

Examples of fish and mammals found in the equatorial open-ocean environment include: mackerel; anchovies; sardines; herring; menhaden; angler fish; sharks; squid; whales; dolphins; and porpoises. Seabirds may also be found in the open-ocean environment, and include auks, albatrosses, petrels, and gannets.[82]

Frequent upwelling of cold, nutrient-rich water at the equatorial divergence supports a highly productive phytoplankton community. However, the equatorial Pacific Ocean is characterized by high nutrient concentrations that are not accompanied by high phytoplanktonic biomass and primary productivity values. Processes such as grazing control, iron limitation and lack of coastal bloom-forming diatoms have been invoked to explain this paradoxical high-nutrient and low-chlorophyll condition.

3.3.5. Marine Species in Atlantic and Pacific Oceans

The Pacific Ocean is the largest ocean in the world followed by the Atlantic Ocean. Island chains are most numerous in the Pacific and volcanic activity around the margins is pronounced. In contrast, the Atlantic is relatively narrow and is bordered by large marginal seas such as the Gulf of Mexico. Its average depth is less than the Pacific Ocean.[83]

The western Pacific is monsoonal (a rainy season that occurs during the summer months), when moisture-laden winds blow from the ocean over the land. Natural resources include oil and gas fields, polymetallic nodules, sand and gravel aggregates, placer deposits, and fish. The West Coast is also host to a wide variety of species, including marine mammals; seabirds; fish, shellfish, and kelp; and intertidal organisms. Marine mammals are predominately pinnipeds (carnivorous, flippered, mammals of the family Otariidae, Phocidae, or Odobenidae) and cetaceans (whales, dolphins, or porpoises).[84] Endangered marine species include the dugong, sea lion, sea otter, seals, turtles, and whales.

In the East Coast, depths range from 0 to roughly 4,000 meters (2.5 miles) in the Atlantic Ocean. Organisms found along the East Coast include phytoplankton and zooplankton, marine macroinvertebrates (such as crabs, shrimp, and squid), fish, sea turtles, and marine mammals. Endangered marine species include the manatees, seals, sea lions, turtles, and whales. Specific areas of the continental shelf waters off the northeastern U.S. coast consistently show high-density utilization by several cetacean species. For example, the western margin of the Gulf of Maine is used most intensively as cetacean habitat. In general, habitat use by cetaceans is highest in spring and summer, and lowest in fall and winter. The Atlantic coastal and offshore areas also contribute significantly to the nation's finfish and shellfish harvests.[85]

4. POTENTIAL ACCIDENT SCENARIOS

In this chapter, background is presented on the safety criteria used by AST in licensing decisions. The operating history of the U.S. LV industry is also examined. Finally, two generic types of accidents are described. These accidents form the basis for the evaluation of environmental consequences from accidents in Section 5.

4.1. AST Safety Considerations in Licensing Decisions

The AST Licensing and Safety Division is responsible for regulating and licensing commercial space launch activities for safety. AST's responsibilities include reviewing license applications for safety adequacy and developing public safety requirements and standards. A Safety Review is a critical part of the licensing process and ensures that license applicants will comply with established requirements and procedures.

Each federal launch range has safety requirements and procedures (e.g., Eastern and Western Range 127-1, Wallops Flight Facility Range Safety Manual). Commercial launch sites will prepare comparable guidelines or, if co-located with a federal range may adopt existing range requirements. U.S. launch sites that are not co-located with a federal launch range will be subjected to AST's licensing and safety requirements.

Although the risk to the public and property can never be completely eliminated, safety systems and procedures such as real-time tracking, flight safety systems, autonomous, on-board, redundant safety systems, and flight path destruct lines are employed to ensure the risks to the public and property are minimized to acceptable levels. Safety destruct lines are chosen to prevent debris from impacting on or near inhabited areas.

4.2. United States Historical Launch Success Rate

The United States commercial space industry is based primarily on technology developed for the government and more specifically for military applications. Thus, an extensive government procurement system, including verifying performance-based specifications from the design to prototype and subsequent manufacturing phases, has already been used for quality assurance and quality control prior to the use of vehicles for commercial markets. This has led to high mission success rates for medium, intermediate and high payload capacity LVs. For example, the Atlas has had 232 successful launches in 267 attempts (86.9% success rate) in the 1958 to 1994 time period. (See Figure 4-1)

Figure 4-1
Atlas IIA Centaur Vehicle (1996)

Similarly, Delta LVs have been successful in 215 of 227 launches (94.7% success rate) from 1960 to 1994. (See Figure 4-2 and 4-3)

Figure 4-2
Delta 7925 Vehicle (1991)

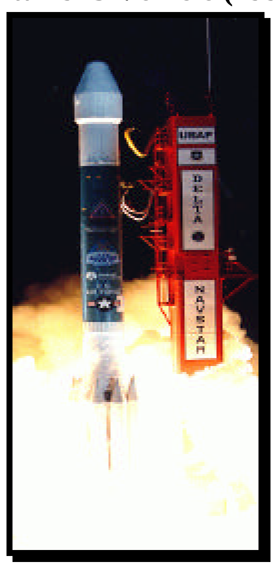
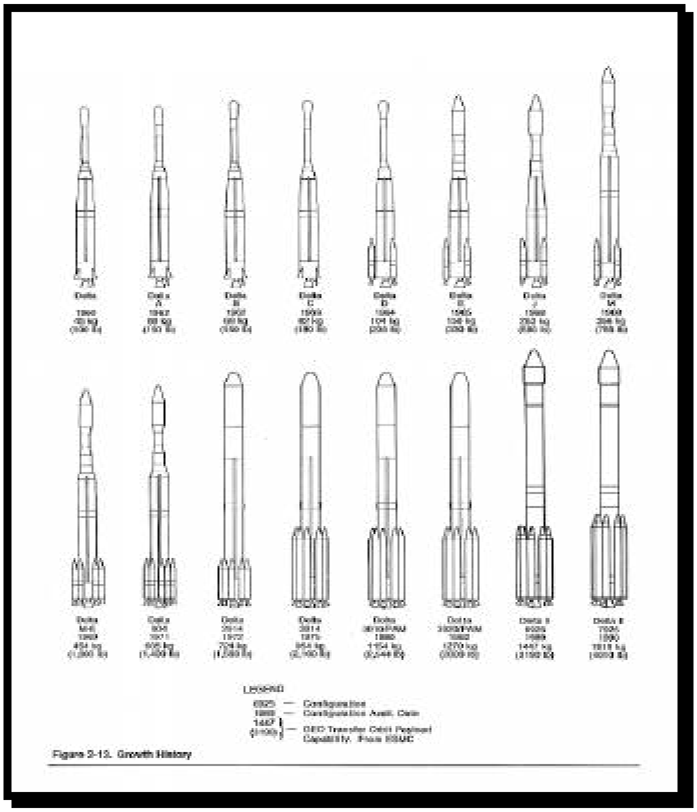
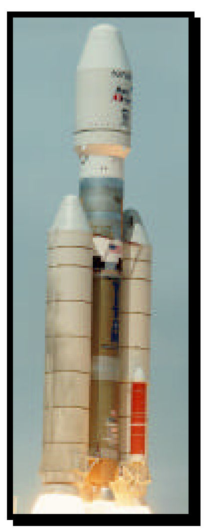


Figure 4-3
Delta Vehicle Series



The Titan, a high payload capacity vehicle that has only been used once for commercial applications, has an overall 93.4% success rate from 1964 to 1994. (See Figure 4-4) Most of the failed launches of these LVs occurred during early vehicle research and development (e.g., approximately the first ten years), and the trend has been for increasingly successful launch rates over time.

Figure 4-4
Commercial Titan 3 Vehicle (1992)



The newer developments in the LV industry have been smaller vehicles that are more cost-effective for placing satellites into LEO. These vehicles have not been used for government-supported launches as have the LVs with larger payload capacity discussed above. Thus, these LVs, which incorporate novel applications of existing technology, may initially experience some launch anomalies and accidents until the vehicle program becomes more mature. The reusable LV approach is also unique, in that it combines operational characteristics of RVs and ELVs.

4.3. Accident on Launch Pad

The scope of this PEIS begins with ignition of an LV's propulsion system. For a land- or sea-based LV, this takes place on a launch pad or platform. An LV's flight termination system is armed prior to launch, and can be fired automatically, or manually any time after the system is armed. The flight safety officer will withhold destruct action, regardless of system failure, until there is a real danger to public safety or property. This may allow a full mission duration to burnout. Launch site personnel are sheltered at a safe distance from the launch pad and are therefore protected from an on-pad explosion. Within the first 10 seconds, the consequences of such an accident could impact the local environments described above in Section 3.3. Such consequences are detailed below in Section 5.3. For an air-based launch platform, an accident occurring in the initial 10 seconds after release from the carrier aircraft could likely expose the aircraft to fragments.

4.4. Accident during Vehicle Ascent

This accident scenario will be discussed in three subsections: (1) ELVs using flight safety systems (FSS) with command in-flight termination capability and range safety systems (currently most existing LVs use these technologies) or with thrust termination (e.g., as is used by a system that is launched from the water); (2) impact ranges for sounding rockets; and (3) alternate safety systems for proposed reusable LVs.

An anomaly that occurs after the LV leaves the launch pad, (or in the case of air-based launches, the aircraft) will result in the use/activation of flight safety systems. Examples of possible anomalies include when the LV does not stay on trajectory, or when the LV experiences system failure (electrical, propulsion, guidance, etc.). The goal of flight safety is to contain the flight of the vehicle and prevent an impact which might endanger human life or cause damage to property.

<u>ELVs.</u> To accomplish this safety objective, real-time flight safety control systems are utilized for ELVs that reliably perform the following functions: (1) continually monitor the launch vehicle performance and determine whether the vehicle is behaving normally or failing; (2) predict (in real-time) where the vehicle or pieces of the vehicle will impact in case of failure and if flight termination action is taken; (3) determine if there is a need to delay or abort the launch or stop the flight of the vehicle, based on a comparison of predetermined criteria with the current vehicle status; and (4) if necessary to protect the public, send a command to abort the mission either by vehicle destruct or engine shutdown (e.g., using a thrust termination system (TTS)).

A flight safety system (FSS) is comprised of several components, the most significant of which, for purposes of discussing accident scenarios, is the flight termination system (FTS). The FTS provides a means of destroying a launch vehicle in the event it deviates from a planned course. Most ELVs carry an FTS to destroy them. Some flight safety systems, however, rely on a TTS instead. Rather than destroying the vehicle, a TTS shuts down the launch vehicle's engines, and halts its thrust so that it does not continue on its previous path. RLVs are expected to employ different types of flight safety systems, as discussed in the second subsection.

The purpose of the flight safety system is to contain the flight of an LV and to prevent impact between an LV or its components and people and property. To that end, prior to launch, a launch operator or launch site will calculate what are commonly referred to as destruct lines. These are lines that show when a vehicle's flight should be terminated so that debris does not reach the public. If telemetry shows a launch vehicle heading outside of the destruct lines, it may be destroyed with an FTS or its thrust terminated with a TTS. Observation, data collection, and calculation constitute the necessary steps in determining whether to terminate the vehicle's flight. Early in flight, visual observation and real-time telemetry measurements provide a means of monitoring the performance of the LV. Radar tracks the position and velocity of the vehicle. An instantaneous impact point (IIP) may be calculated using the velocity and position of the LV. An IIP is calculated as a moving point on the Earth, and it shows where a launch vehicle (or its pieces) would land were the vehicle to stop moving. For ELVs equipped with an FSS with an FTS command flight termination capability, if a vehicle's IIP crosses a destruct line, mission control transmits a signal to activate the FTS to destroy the vehicle. This produces a liquid propellant tank rupture. Depending on the mixture of liquid propellant used and the altitude at which the flight is terminated, propellants will most likely be instantly vaporized. Flights terminated at lower altitudes might produce very limited pooling of liquid fuel on the ground or water surface being overflown. In addition to vaporization in the atmosphere, any such pools would also quickly evaporate. Unspent solid rocket motors and other debris would land at or near the IIP. If flight is terminated when the solid rocket motors are already ignited, their integrity is destroyed. Although propellant pieces might continue to burn until impact, most solid propellants do not continue burning when the propellant grain is broken and no longer under pressure. Vehicle destruction is designed so that impacting pieces land within an established area (the area calculated along the trajectory of flight within which debris is expected to fall). For launch of an ELV over water, the consequences of an accident at this point in the flight profile would be limited to the atmosphere and the oceans. These consequences are discussed in Section 5.

In the case of an LV using a TTS as part of its flight safety system, the engines are shutdown but the liquid propellant tanks and SRMs are not ruptured. TTS systems are proposed for ELVs being launched from the ocean, therefore these components would fall back into the ocean. The consequences of an accident at this point in the flight profile would also be limited to the atmosphere and the oceans. These consequences are discussed in Section 5.

Under these accident scenarios, the activation of the flight safety systems (and in-flight vehicle termination or TTS) serves to minimize the potential safety and environmental consequences. Prior to issuing a launch license, AST reviews in detail the location of the launch , the functioning of the flight safety systems, and the license applicant's procedures to ensure activation of flight termination or TTS when needed. Thus, the license application review conducted by AST has the effect of minimizing the potential for consequences of accidents during LV ascent.

Sounding Rockets. Sounding rockets are used to conduct scientific experiments by lifting payloads to altitudes as high as 1,500 km. Sounding rockets do not deliver payloads into orbit but rather return to earth after a rapid ascent. The first stage of a sounding rocket, when spent, lands between 0.3 and 1.5 km from the launch pad with an impact weight in the 270- to 800-kg range.[86] Small weather and test spent rockets (impact weight of 7 to 9 kg) land between 2.8 and 8.8 km from the launch pad. Thus, for the nominal launch, safety is achieved by clearing an area around the launch pad and assessing the risk of nominal stage impact. For multiple stage sounding rockets, medium-range and final-stage spent rockets have impact ranges up to hundreds of kilometers, and the accident scenarios described above are applicable.

Reusable Vehicles. Reusable vehicles are not designed to jettison spent stages into an ocean, but instead return to a fixed location on the ground within a restricted use landing area. Existing proposals describe launch over land. Such a vehicle would undergo extensive safety review prior to and during the AST license application process. Key features of one proposed reusable vehicle are:

- redundant avionics,
- redundant triggering system for “soft” landing of components using parachutes and air bags,
- “engine-out” capability to land under guidance in the event of an engine shut-down,
- use of emergency diversion locations within undeveloped and restricted access land,
- coordination with FAA commercial use airspace,
- precise de-orbit burn by using global positioning system and orbital maneuvering system engines, and
- use of attitude control jets to make trajectory corrections during guided re-entry.

Although the items listed above would be incorporated into the reusable LV design, as currently proposed such an LV would not necessarily be equipped with a traditional flight safety system with in-flight termination capability. Thus, impacts of an accident during ascent could include the possibility of uncontrolled landing (assuming multiple failures of redundant systems). Further, the vehicle structure and some propellant tanks will be comprised of composites or FRP (fiber reinforced plastics). The fiber can be glass, carbon, or aramide (an organic polycyclic material) filament, mat, or tape. RFP composites provide high tensile strength, low density, low weight material for structural components and tanks. The consequences and possible impacts of an accident involving the potential burning and partial breakup of composite vehicle structures cannot be adequately assessed at this time because final materials and fabrication processes have not yet been determined. Further analysis will be done during review of specific launch application technical data and site-specific environmental documentation.

5. ENVIRONMENTAL IMPACTS AND CONSEQUENCES OF THE PREFERRED ALTERNATIVE

Environmental impacts to the atmosphere associated with launching LVs are addressed in the first section. Section 5.2 assesses the noise impacts experienced by receptor type (i.e., human, wildlife, structures). In Section 5.3, other potential environmental impacts are addressed including the probability assessment of marine mammal strikes. The potential impacts are assessed using the six environment types and information on marine species in the oceans previously described in Section 3.3. Socioeconomic impacts are described in Section 5.4, and environmental justice impacts are reviewed in Section 5.5. The potential environmental impacts of the more environmentally-friendly propellant combinations alternative are addressed in Section 5.6. For the no action alternative, all of the impact areas are considered in Section 5.7.

5.1. Potential Atmospheric Impacts

In this section, atmospheric impacts are assessed beginning at ground level with consideration of tropospheric effects (i.e., total atmospheric load from the ground cloud near launch site and acid rain). Stratospheric effects, including global warming, ozone depletion, and acid rain, are detailed in subsection 5.1.2. No mesospheric effects have been identified (subsection 5.1.3). The potential for changes in ionosphere electron concentrations is assessed in subsection 5.1.4. Consideration of local potential impacts from a ground cloud near a launch site is found in Section 5.3.1.

5.1.1. Troposphere

The main potential impacts to the troposphere may result from the ground cloud formed from the ignition of rocket motors and the resulting launch of the LV. Other potential impacts to the troposphere could result from accidents on the launch pad or during flight.

Ground Cloud Near Launch Site. A ground cloud forms within the first 10-12 seconds of an LV launch. It is composed of a complex mixture of gases, dissolved and particulate exhaust products, water used for fire and sound suppression, and materials ablated from the physical surfaces on and around the launch pad. Table 5-1 shows the major exhaust products from propellants that are currently used in spaceflight or are under development. [87, 88, 89, 90, 91, 92]

TABLE 5-1
MAIN EXHAUST PRODUCTS FROM PROPELLANT SYSTEMS

Solid	Liquid Hydrocarbon	Hypergolic	Cryogenic	Hybrid Propellant
HCl, Al_2O_3, CO, N_2 CO_2, NO_x, Cl^-, H_2O	CO_2, CO, H_2, H_2O, OH^-	CO_2, CO, NO_x, N_2, H_2O, H_2	H_2O, H_2	CO, CO_2, H_2, H_2O, NO_x, OH^-

Of the chemical species that form during ground cloud formation, the most environmentally significant are HCl, Al_2O_3, NO_2, and CO_2. Not all of these chemicals are produced by the various propellant systems. HCl and Al_2O_3 will be discussed below. NO_2 is primarily produced by hypergolic propellants systems and is very toxic. However, liftoff thrust from current U.S. commercial LVs is not provided by hypergols and therefore, the ground cloud concentration of NO_2 should be very small.

Environmental effects from CO_2 occur in the stratosphere and therefore are discussed in Section 5.1.2. The other emissions are either insignificant or will not be harmful to the troposphere. CO is assumed to convert to CO_2; OH converts to water vapor and is emitted in very small quantities; and some N_2 is converted to NO_x. Table 5.2 summarizes the emissions to the troposphere by LV payload capacity and propellant types.

TABLE 5-2
ESTIMATED EMISSIONS IN THE TROPOSPHERE PER LV LAUNCH BASED ON PAYLOAD AND PROPELLANT TYPE (KG AND TONS)

Payload Capacity	Propellant Types	HCl Load		Al_20_3 Load		CO_2 Load*		H_2O Load	
		kg	tons	kg	tons	kg	tons	kg	tons
Small	Solid	7,875	8.7	14,250	15.7	17,250	19.0	10,125	11.1
Medium	Solid	9,450	10.4	17,100	18.8	20,700	22.8	12,150	13.4
Intermediate	Solid	14,175	15.6	25,650	28.2	31,050	34.2	18,225	20.0
	Solid/LOX-RP1	7,087.5	7.8	12,488	13.7	47,250	52.0	17,550	19.3
	LOX-RP1	-	-	-	-	62,775	69.1	16,875	18.6
	Hybrid	-	-	-	-	62,775	69.1	16,875	18.6
High	Solid	44,100	48.5	79,800	87.8	96,600	106.3	56,700	62.4
	Solid/LOX-RP1	22,050	24.3	38,850	42.7	147,000	161.7	54,600	60.1
	Hybrid	-	-	-	-	195,300	214.8	52,500	57.8

*CO_2 estimate includes CO_2 formed by oxidation of CO in the exhaust plume. See Appendix A for background on assumptions and calculation of emissions.

Models, such as the Rocket Exhaust Effluent Diffusion Model (REEDM), are typically used to estimate the impacts of emissions from rocket launches. These models calculate peak concentrations and surface deposition near the launch pad and downwind. The models are based on inputted meteorological data such as wind speed, cloud height, wind direction, air temperature, atmospheric pressure, and relative humidity.

As the LV gradually accelerates off the launch pad, the emission levels are greater near the ground, forming the 'ground cloud.' For large space vehicles, this cloud may rise to 1 km or more before stabilizing. Its height remains relatively constant as it is transported and dispersed downwind.[93] The ground cloud can be generated by gaseous and aerosol phases of the exhaust products. The aerosols are generally water droplets containing dissolved HCl and particulate Al_2O_3. The larger droplets tend to deposit near the launch pad. The quantity of aerosol deposition is affected by the amount of deluge water used, the amount of water produced by combustion, and the water content and temperature of the ambient air that mixes with the ground cloud. The amount of aerosol is less with a drier ground cloud.[94]

Hydrogen Chloride. HCl is an HAP and is toxic, corrosive, and an irritant. EPA regulates 188 HAPs, including HCl, but launch vehicles are not included as one of the regulated source categories. However, because HCl is toxic, its impacts are considered for this PEIS. In the troposphere, HCl emissions from LVs are estimated to be approximately 9 to 50 tons per launch for vehicles that use SRMs (see Table 5-2).

To analyze the impacts of the ground cloud, the quantity of HCl is compared to the HCl threshold limit value (TLV) (the exposure limit value set by the Occupational Safety and Health Administration

(OSHA) protecting workers over an 8-hour day and a 40-hour week). In this case, the TLV is 5 ppm or the one-time short-term public emergency guidance level (SPEGL) developed by the National Research Council of 1 ppm as a ceiling concentration.[95] The TLV expresses the upper limit of a toxicant concentration that a healthy human being can be exposed to on a daily basis without experiencing adverse health effects. Modeling using REEDM conducted for other analyses has shown HCl concentrations of 0.9 ppm for the Space Shuttle, 0.005-0.5 ppm for the Titan III, 0.22 ppm (one-hour average) for the Titan IV-Type 1 with SRM (the maximum one-hour average HCl value for the nearest Vandenberg off-base location is 1.0 ppm), and less than 2 ppm (30 minute average) for the LMLV-2.[96,97,98,99] Furthermore, REEDM predicted a maximum HCl ground-level concentration of 0.8 ppm at a downwind distance of 8 miles from the commercial Atlas IIAS. Maximum ground level concentrations of 1.2 ppm were predicted for the conflagration of the Atlas IIAS vehicle, and 1.8 ppm for the burning of the solid rocket motor storage facility.[100] Studies of the Titan III and the Space Shuttle have shown maximum HCl concentrations at the TLV of 5 ppm for 10 to 60 minutes after the launch at 1 to 2 kilometer above ground level.

On a global level, as shown in Appendix A, a conservative estimate of LV HCl emissions over a ten year period is approximately 5,024 tons. Even if all of these HCl emissions occurred in one year, the impacts on acid rain would be minimal. Acid rain is formed when the HCl absorbs in moisture (e.g., rain) and deposits on the ground. These HCl emissions can be compared to the annual U.S. SO_2 emissions, the major pollutant contributing to acid rain in the U.S. The total allowable levels of electric utility SO_2 emissions from fossil fuel combustion; industrial processes; solvent use; waste incineration; and fossil fuel production, distribution, and storage in the U.S. are estimated to be 21 million tons for 1994. In comparison, LV HCl emissions would be only a very small fraction (< 0.02%) of the U.S. acid-rain producing emissions.

On a local level, the effects of acid rain may be somewhat more significant. HCl from LVs may also contribute to acid rain that can change the pH levels in water, killing small fish and damaging or potentially killing trees and vegetation. Intermediate to high payload capacity vehicles have resulted in acid rain with a pH of one at about five km from the launch pad and a pH of two at about 10 km away. Based on high payload capacity vehicle launches using solid rocket motors, modeling has estimated the pH levels of rain to be less than one for up to 20 km from the launch pad and less than or equal to two up to 200 km away.[101] Usually, the impacts of acid rain occur within less than one-half mile from the launch pad. For large capacity vehicles (using solid propellants), acid rain has been shown to affect areas within one-half mile of the launch pad.[102]

The cumulative impact of HCl caused by rocket launches has not been studied significantly to report in this DPEIS. Scientists do think this may be an issue that warrants study and are beginning projects to determine what, if any, cumulative effect HCl generated from rocket launches have on the atmosphere. The results of any credible studies will be subject to further analysis during site-specific environmental analysis and documentation.

<u>Aluminum Oxide.</u> Al_2O_3 is not toxic but is particulate matter that could potentially cause irritation and damage to human respiratory tracts if it bypasses the natural human filtering systems. Only particulate matter less than 2.5 microns in size is regulated by EPA. Most of the particles of Al_2O_3 are assumed to be greater than 10 microns in size. In the troposphere, emissions of Al_2O_3 from LVs are estimated to be 14 to 90 tons per launch for LVs with solid rocket motors.

The specific effects of particulate matter on air quality are dependent on meteorological data (wind speed and direction, mixing heights of air, temperature) and site-specific receptors. To determine the impacts of Al_2O_3, modeled concentrations may be compared to the National Ambient Air Quality Standards for PM_{10} (150 $\mu g/m^3$ for 24-hour average and 50 $\mu g/m^3$ for annual average). One modeling analysis using REEDM estimated the PM_{10} concentrations for 24-hours to be 25 $\mu g/m^3$ (for a Titan IV-Type 2) above background PM_{10} concentrations.[103]

The cumulative impact of AL_2O_3 from rocket launches, much like the cumulative impact of HCl, has not been studied. Should any credible studies be completed, their results will be subject to further analysis during site-specific environmental analysis and documentation.

5.1.2. Stratosphere

In the stratosphere, LV emissions could potentially affect global warming (the greenhouse gas effect) and depletion of the stratospheric ozone layer.

Global Warming. The Earth absorbs energy from the sun and radiates this energy back into the atmosphere. The greenhouse gas effect, or global warming, results when the re-radiated energy is trapped by gases in the atmosphere and warms the Earth's surface and atmosphere. Greenhouse gases include water vapor, carbon dioxide, methane, ozone, chlorofluorocarbons (CFCs), hydrofluorocarbons, and perfluorinated carbons. Note that ozone exists in both the troposphere and stratosphere. Most ozone is found in the stratosphere where it provides a protective layer shielding the Earth from ultraviolet (UV) radiation and subsequent harmful effects. Some ozone is transported to the troposphere. In the troposphere, ozone is a chemical oxidant and a major component of smog.

Other photochemically important gases such as carbon monoxide (CO), nitrogen oxides (NO_x), and nonmethane hydrocarbons (NMHC) are not greenhouse gases, but contribute indirectly to the greenhouse gas effect. These indirect contributors influence the rate at which ozone and other gases are created and destroyed in the atmosphere. Sulfur gases, especially sulfur dioxide emissions, are believed to contribute negatively to the greenhouse gas effect.

The potential LV emissions that may affect global warming include water vapor and CO_2. For most greenhouse gases, a global warming potential has been developed to allow for comparison of the ability of each greenhouse gas to trap heat in the atmosphere. However, no global warming potential has been developed for water.

The total CO_2 emissions range from 19 to 215 tons per launch, depending on the LV's payload capacity and propellant type. The estimated total CO_2 emissions from LV launches into the troposphere for the period 1998-2009 is 25,000 tons (see Appendix A). In comparison, the total CO_2 emissions from all sources in the U.S. was 5,687 million tons in 1994. Even if all of the launches occurred in one year, based on 1994 CO_2 emission levels, these launches would only be a very small fraction (less than one percent) of the total CO_2 emissions. Consequently, the CO_2 emission effects from LVs on global warming will be insignificant. The total water vapor generated is approximately 11 to 62 tons per launch, or about 10,000 tons for the period 1998-2009. In comparison, the total carbon-equivalent direct and indirect emissions effects (excluding the photochemically important emissions) in the U.S. were 1,835 million tons in 1994. Water vapor from LVs will also have an insignificant effect on global warming.

Ozone Depletion. Stratospheric ozone layer depletion is a major environmental concern. The stratospheric ozone layer protects the Earth from adverse levels of UV radiation. Excess UV exposure can lead to increased incidences of skin cancer, sunburn, and immune deficiencies. The protective ozone layer is mostly contained within the stratosphere, an area that extends from approximately 10 kilometers to 50 kilometers above the Earth's surface.

As stated in section 3.1.2, the highest concentrations of ozone are found in the middle of the stratospheric layer and ozone is continually created and destroyed by naturally occurring photochemical processes. Ozone is made up of three oxygen atoms and is generated by the action of sunlight to combine an O_2 with an atom of oxygen. Conversely it can be destroyed through a series of photochemical reactions that can catalyze the reactions $O + O_3 = 2O_2$ and $2O_3 = 3O_2$ of compounds that break up O_3 into various other compounds. The following presents the chemical and photochemical processes that are important in the formation of ozone from molecular oxygen in the stratosphere and the reactions associated with ozone destruction.

Ozone Destruction[104]

$O_3 \rightarrow O + O_2$

$O_3 + O \rightarrow 2O_2$

$Cl + O_3 \rightarrow ClO + O_2$

$ClO + O \rightarrow Cl + O_2$

$H + O_3 \rightarrow HO + O_2$

$HO + O \rightarrow H + O_2$

$OH + O_3 \rightarrow HO_2 + O_2$

$O + HO_2 \rightarrow OH + O_2$

$NO + O_3 \rightarrow NO_2 + O_2$

$NO_2 + O \rightarrow NO + O_2$

$Br + O_3 \rightarrow BrO + O_2$

$BrO + O \rightarrow Br + O_2$

Ozone Production

$O_2 \rightarrow 2O$

$O + O_2 + M \rightarrow O_3 + M$

Chlorine and bromine are of most concern with respect to ozone depletion. Human activity has significantly contributed to the chlorine and bromine load levels in the stratosphere. Chlorine accounts for approximately 13% of ozone destruction, and bromine is responsible for an even smaller proportion.[105] Rocket launches are one of the anthroprogenic sources of chlorine in the stratosphere.

Emissions from rocket engines, including commercial LV launches, are of concern because during about 60 seconds of their ascent they inject substances that can lead to ozone depletion (HCl, Al_2O_3, NO_x, and Cl) directly into the stratosphere. Most of the studies focus on HCl emissions because the other emitted chemicals were believed to have shown a very small effect on ozone depletion. HCl emissions from SRMs are of primary concern because of the large quantity released and because HCl is a source of chlorine. HCl can deplete ozone, therefore it must be photolyzed to release the Cl. Some of the HCl gets mixed into the troposphere and rained out before it is photolyzed. Thus, it has a chance to destroy ozone.

Beside gases, SRMs release particulates and Al_2O_3. Attempts to determine the distribution and effect on ozone depletion of particulates and Al_2O_3 have been limited. Therefore the current models are based upon homogenous gas phase chemistry, which act as a site for the ozone depleting reaction. The significance of this stage is unclear. Heterogeneous chemistry (which accounts for particulates, plume temperature and afterburning of fuel-rich exhaust) are not included in this PEIS, because there are very limited data and modeling available to date. However, future analysis of rocket launches using heterogeneous chemistry could alter the understanding of potential impacts of LVs on stratospheric ozone-depletion.[106] In terms of local ozone depletion in the general exhaust of the rocket, limited field data and several computer models have estimated local ozone depletion from 7 to 40 percent for several minutes and hours after the launch. Winds rapidly disperse the exhaust and return the ozone to approximately normal levels.

The current field study on Rocket Impact on Stratospheric Ozone (RISO) has confirmed that ozone depletion related to LV emissions is a temporary and limited phenomenon. Initial results from this study have indicated that LOX kerosene engines may be more potent in ozone depletion than previously expected. Thus additional data collection is ongoing to further evaluate LOX/kerosene exhaust impacts. Ground lidar results from this study have indicated that (1) the relative rates or plume expansion and diffusion are quite different than previously assumed; (2) stratospheric plumes stratify into stable layers only several hundred meters thick; and (3) large SRM aerosol emissions consist of alumina and also a Rayleigh scattering aerosol that disappears within 90 minutes of launch and does not appear in plumes above approximately 35 km. In general, preliminary findings from this study indicate that the potential for ozone depletion associated with LV exhaust to cause an increase in solar UV intensity near launch sites is extremely limited.[107]

There has been extensive research on the potentially harmful effects of large solid rocket exhaust on global ozone depletion by the Air Force and the National Aeronautics and Space Administration (NASA). These studies are generally based on a high launch rate, which allows for evaluation of large HCl and Cl loads to the stratosphere. One such study by the World Meteorological Organization examined the effects of ten launches of each of the following vehicles per year: Space Shuttle, Titan IV, and Ariane 5, which release 68, 32, and 57 tons of Cl per launch, respectively, directly into the stratosphere.

A total of 1,570 tons of Cl deposited in the stratosphere each year from these launches corresponds to only 0.064% of the 1994 total stratospheric burden of chlorine from industrial sources.[108] Analyses in the RISO study have confirmed that ozone loss occurs in the plume wakes of large SRMs (e.g., Titan IV and Space Shuttle LVs), but the amount and duration of the loss appears limited. Interestingly, the effect is greater with the Titan IV as compared to the Shuttle, but the differences in the causative plume chemistries are not well understood.[109]

In comparison, SRMs on commercial LVs are smaller than those on the Space Shuttle and the upgraded SRMs on the Titan IV. The specific HCl input to the stratosphere from rocket exhaust can be estimated if the HCl amount and its time-dependent releases along the ascent are known. Using the number of launches estimated in Section 2.0, emission loads of HCl in the stratosphere for all U.S. commercial LV launches from 1996 - 2005 are approximately 5,024 tons, and the additional free Cl load is 67 tons. This averages to approximately 509 tons of HCl and Cl load to the stratosphere from U.S. commercial LV launches per year. (See Appendix A, Emission/Afterburning Products and Loads for a detailed methodology determining numbers and emissions loads.) The RISO study results indicate that ozone depletion related to alumina emissions from SRMs is proportional to the fraction of alumina in the smallest size mode. Previous estimates have suggested that about 10 percent of SRM alumina is in the smallest size mode, while RISO measurements indicate that only about 0.1 percent of SRM alumina is in the smallest mode. This suggests that the role of SRM-emitted alumina may be less important in global atmospheric reactions than was previously estimated.[110]

In the environmental assessment of the Atlas IIAS,[111] a comparison was made between the effect of an Atlas IIAS and a Titan IV on ozone depletion. The ozone depletion from three Titan IV launches per year would be approximately 0.01% - a conservative estimate because it assumed all of the emissions would migrate to the stratosphere. An Atlas IIAS launch would emit approximately 7.9 tons of HCl, compared to 145.5 tons emitted by a Titan IV launch. Therefore, by simple ratio, the estimate of peak ozone depletion due to six Atlas IIAS launches per year would be 0.001% of total ozone depletion.

Another study entitled "Atmospheric Environmental Implications of Propulsion Systems" concluded that even vastly increased space launch activities (50 Space Shuttle or Energia launches per year) would not significantly impact stratospheric ozone depletion.[112] A comparison in this study was made between the chlorine loads in the stratosphere from rocket launches and the chlorine loads from other natural and man-made sources. The primary sources of ozone depleting chemicals are CFCs and other man-made ozone-depleting chemicals, and natural sources from the oceans, burning vegetation, and volcanic eruptions. It is also noted in this article that rockets release mostly HCl into the stratosphere. Thus, although the preferred alternative would increase the Cl load to the stratosphere, the global effects would be far below and indistinguishable from the effects caused by other natural and man-made causes. Even with the production ban on CFCs, HCFCs, and methyl bromide, rocket exhaust from commercial LVs (similar to any given manmade source of HCl considered in isolation) will remain an insubstantial part of the overall chlorine load to the stratosphere over the next 50 years due to the long-life of CFCs. Nonetheless, the serious nature of the problem of ozone depletion implies that all sources must be considered. Hybrid propulsion systems have the potential to greatly reduce the HCl emitted from rocket exhaust into the stratosphere. The hybrid propulsion systems, currently undergoing testing, burn solid fuel (aluminum) and a cryogenic oxidizer (LOX). Thus, these propellants do not release HCl when burned.

In summary, the LV emissions that may affect global warming include water vapor and CO_2. However, there is currently no way to study the effects of water vapor from LV emissions on the greenhouse effect. The total amount of CO_2 that is released from LV launches is thought to be so much less than the contributions of CO_2 by other industries as to make rocket lunches an insignificant source of CO_2. Protecting the stratospheric ozone layer is a major global concern. Emissions from commercial LVs do contribute to the creation of "holes" in the stratospheric ozone layer as the rocket passes through although these "holes" tend to "fill back in" rapidly following a launch. The amount of depletion depends on the type of propellants used.

5.1.3 Accidents in the Troposphere and Stratosphere

The impacts from accidents on the launch pad or as a result of a flight anomaly requiring the use of a flight safety system may, impact the air quality in the atmosphere at the time of the accident. However, because of the infrequency of these events, the overall impact in comparison to other emission sources is not substantial. The impacts of accidents are typically described by propellant type. However, some rockets may use a combination of propellants.

Accidents on the launch pad would result in significant air emissions. The impacts would differ from normal flights because all or a larger portion of the propellant would burn at the launch pad or within the first 10 seconds after ignition.

<u>SRMs.</u> The emissions of most concern for rockets using solid propellant systems are HCl, CO, CO_2, Al_2O_3, and NO_x. The rate at which the solid propellant would burn depends on the size of the solid fuel fragments and the air pressure.[113] Open burning of all the propellant may release approximately 3,200

kg (3.5 tons) of HCl emissions; 3,520 kg (3.9 tons) of CO_2 emissions; 2,720 kg (3 tons) of CO emissions; 6,434 kg (7 tons) of Al_2O_3 emissions; and 550 kg (0.6 tons) of NO_x emissions, based on the CASTOR 120™ boosters and approximately 49,033 kg (108,100 lbs) of propellant. Solid propellant is broken into relatively small pieces and only a small percent of it burns completely. Therefore the amounts released from a failed vehicle launch may be less than these estimates however, emissions will be higher in vehicles with larger solid rocket motors.

The HCl may combine with moisture in the air and form hydrochloric acid. This vapor may exist in hazardous quantities in the immediate vicinity of the launch pad and downwind. High wind conditions (greater than 4 miles per hour) and strong sunshine could dissipate the HCl concentrations.[114] The HCl may also be washed out by moisture in the air causing acid rain most likely within close proximity to the launch pad. The CO and NO_x emissions could impact the air quality in the area for that day especially if the area is nonattainment and does not meet the National Ambient Air Quality Standards for CO, NO_x or ozone (since NO_x is a precursor). The NO_x emissions could also contribute to local acid rain. The CO_2 emissions could affect global warming, but compared to other sources of CO_2 emissions, accidents would result in negligible impacts. The Al_2O_3 emissions would occur mainly in slag-form and thus would not create particulate matter emissions.

<u>LOX-RP1</u>. For LVs using LOX-RP1 propellants and hybrid propellant, the CO_2 emissions would be the most significant. As noted below, the CO_2 emissions could affect global warming, but even with the open burning of all the propellant, these emissions from LV accidents would be negligible compared to the rest of the CO_2 emissions sources in the U.S. and worldwide.

<u>Hypergols</u>. If a rocket had a rapid, sudden explosion of hypergolic propellant (mainly nitrogen tetroxide (N_2O_4)-aerozine-50 (a mixture of 50 percent, by weight, hydrazine and 50 percent unsymmetrical dimethylhydrazine) (A-50)), the release of N_2O_4 would create NO_2 emissions. For the Titan IV, the REEDM model was used to characterize this type of event. For this modeling, 80 percent of the N_2O_4 and 20 percent of the A-50 was assumed to remain unreacted. These assumptions were based on an observation of a destruction of the Titan 34D at 800 ft above the launch pad in 1986. Assuming that the hypergolic propellant system in a Titan IV rocket is about 155,000 kg, the amount of N_2O_4 (approximately 102,000 kg) would be almost twice the amount of A-50 (approximately 51,000 kg). The N_2O_4 disassociates almost completely in the ambient air and forms NO_2. This modeling analysis of the Titan IV predicted that the maximum one hour NO_2 concentrations would be 1.09 ppm at a distance greater than 10 miles (16 km). This concentration exceeds the SPEGLs recommended by the National Research Council 1-hour concentration of 1.0 ppm.[115] The toxic NO_2 emissions from accidents may impact the air quality in the region of the launch pad perhaps endangering nearby residents. NO_x may also contribute to the development of acid rain. With the NAAQS, EPA regulates NO_x emissions alone and as a tropospheric ozone precursor, although not specifically from rockets. EPA does not provide a maximum NO_x concentration level for a short-term averaging period; however, a short-term (1-hour) standard is provided for ozone (0.12 ppm). The relationship between NO_x and O_3 is complex. Sometimes, NO_x emissions contribute to the formation of ozone; other times, NO_x emissions prevent ozone formation.

<u>Cryogenics</u>. LVs using cryogenic propellants, LOX and LH_2, would mainly emit water vapor.

Accidents where a flight safety system is activated may result in the burning of the remaining propellant in the atmospheric layer where the termination occurs. If the accident occurs in the troposphere, all of the propellant may burn. The emissions would be similar to those described for an accident on the launch pad; however, the impacts may not be as local. For accidents with flight safety system activation in the stratosphere, the remaining propellant may burn. The emissions from such an accident, would be expected to be insignificant with respect to global warming and most likely less than the emissions expected from a normal, full duration launch.

5.1.4 Mesosphere

In this analysis, no impacts to the mesosphere are predicted during nominal launches. If an accident occurs in the mesosphere, the emissions would be greater than a launch pad accident, but no additional impacts would be predicted on the mesosphere.

5.1.5 Ionosphere

Some exhaust products from LVs generated during launch from Earth to space have been found to have a temporary effect on electron concentrations in the F layer of the ionosphere. Specifically, these exhaust products are CO_2, water, and atomic hydrogen. These compounds can react with ambient electrons and ions in the F layer of the ionosphere to effectively form a "hole" in this region by reducing the concentration of electrons and ions within the path of the vehicle.

This effect in the F layer is believed to be caused by a rapid charge-exchange reaction between the LV exhaust products and the ambient atomic oxygen ions in the F layer. Ambient atomic oxygen ions (O+) are the dominant ion in the F layer. At lower altitudes of the ionosphere (i.e., below 140 km), this reaction is not effective because the dominant positive ions are NO^+ and O_2^+, not O^+. For example, the reaction between water and O+ is as follows:

$H_2O + O^+ \rightarrow H_2O^+ + O$ followed by the rapid recombination
$H_2O^+ + e^- \rightarrow OH^- + H^-$

Similar reactions also occur with carbon dioxide and hydrogen. These reactions result in a net decrease in electron concentration in the F layer, potentially affecting radio communication, such as short-wave broadcasts, which interact with the ionosphere.[116]

An experimental test firing of the propulsion unit used by the Space Shuttle for maneuvering within the ionosphere was conducted in 1985. This test firing provides some data on the rapidity with which a "hole" in the F layer may disappear. The propellants used in this test firing were monomethylhydrazine (MMH) and nitrogen tetroxide (N_2O_4), similar to the propellants used for routine launches of other LVs. However, the quantities of propellants consumed for this test are smaller than the quantities of propellants consumed during launches of medium to large-scale capacity LVs.

The test involved consuming 290 kg (640 pounds) total mass of MMH and N_2O_4. Exhaust products from this experimental test firing consisted of approximately 117.7 kg (40.6 percent) nitrogen, 92.5 kg (31.9 percent) carbon dioxide, 75.7 kg (26.1 percent) water, and 4.1 kg (1.4 percent) hydrogen. The percentages represent percent by mass, and complete combustion was assumed. Thus, about 172 kg of potential electron-depleting substances (CO_2, H_2O, and H) were emitted. The associated "ion/electron hole" disappeared into the lower F layer within five minutes.

This quantity of by-products represents only 0.2 percent of by-products produced in the upper atmosphere during a typical launch from Earth to space.[117] Using the same methodology used in Appendix A of this PEIS to estimate emission loadings to the stratosphere and troposphere, rough estimates of electron-depleting loadings to the ionosphere were also calculated. These loadings were estimated for the four vehicle capacity types (i.e., small, medium, intermediate, and high) and three categories of propellant type (solid, liquid and hybrid, and hypergolic). A small vehicle burning only solid propellant would emit approximately 100 kg of electron-depleting substances (CO_2, H_2O, and negligible H), similar to the test results above. However, a medium vehicle burning both solid and hypergolic propellants in the ionosphere would emit approximately 2,400 kg of electron-depleting substances (CO_2, H_2O, and H), 14 times greater than the test results above. Table 5-3 provides estimates of estimated propellant consumption in the ionosphere by vehicle capacity category and propellant type.

TABLE 5- 3
ESTIMATED PROPELLANT CONSUMPTION IN THE IONOSPHERE BY VEHICLE CAPACITY CATEGORY AND PROPELLANT TYPE

	Solid	Cryogens	Hypergolic	Hybrid
Small	1000 kg			
Medium	5000 kg		4,500 kg	
Intermediate	20,000 kg	20,000 kg	20,000 kg	20,000 kg
High		32,000 kg	32,000 kg	32,000 kg

Data are unavailable to estimate the differences in the size of the “ion/electron hole” that might be created with larger vehicles and the amount of time it would take for these holes to dissipate. As stated earlier, an important variable concerning whether or not there will be ionospheric effects is location of the final parking orbit. For example, the 12 Saturn V rockets launched during the Apollo program did not cause an ionospheric hole measurable from the Earth’s surface because all of their final parking orbits (and therefore their second stage burns) were below 190 km (where the ionospheric chemistry is different from the F-layer). (See Figure 5-1)

Figure 5-1
Saturn V Launch Vehicle (1969)

However, the Saturn V launch of Skylab did create a sizable ionospheric hole, because orbital insertion of this launch occurred at 442 km.[118] In the worst case, these holes appear to dissipate in a matter of minutes. Therefore, it does not appear that the effects of this phenomena could accumulate to any degree, unless there were launches through the same region of space every few minutes.

5.2 Potential Noise Impacts of the Preferred Alternative

The noise impacts are assessed by receptor type. In the affected environment (Section 3.2), the activities under the preferred alternative which could potentially lead to impacts are described (e.g., launches, sonic booms). In this section, three receptor categories are identified: humans (subsection 5.2.1), wildlife (subsection 5.2.2), and structures (subsection 5.2.3). For each type of receptor, the potential impacts of launch activities are detailed in the appropriate subsection.

5.2.1 Noise Impacts on Human Beings

Human annoyance is best predicted by L_{dn} levels, as detailed in Section 3.2. There are two different methods to accomplish this: predict the overall noise level and/or predict the increase in noise level. There is fairly good agreement that L_{dn} levels above 65 dBA affect communities. Furthermore, studies have been done which predict annoyance and community reaction as a function of L_{dn}. Data presented by EPA indicate that at 65 L_{dn}, 30 percent of the population is "highly annoyed," resulting in 5 percent filing complaints and some threats of legal action. Other survey results suggest that the 65 L_{dn} may only result in 10% of the population being "highly annoyed."[119] Increments of 3 dBA are usually associated with the lowest increase perceptible to the human ear and an increase of 5 dBA can be considered significant.

There are two reactions people may have to single event noise from commercial LV launches. The first is an uncomfortable feeling due solely to the noise level. The second is a startle effect, due to the impulse noise of sonic booms and their associated noise levels. Preliminary results of recent research suggest that people are more sensitive to sonic boom noise than other types of noises at similar levels, including aircraft noise around airports. Therefore, the effects of sonic booms are discussed separately, below. Based on predicted dBA levels, people may perceive launch related rocket noise to be "very loud" out to a distance of 3 miles. Assuming no barriers lessen the noise, the level would be considered "loud" out to anywhere from 10 to 35 miles from the launch pad.

There are three concerns regarding sonic boom effects on humans:(1) health, (2) startle, and (3) annoyance. To put these concerns into prospective, Table 5-4 presents overpressures and common noise sources. In the expected overpressure range for the proposed activities, two to three pounds per square foot, a cap gun or firecracker near the ear would be an equivalent noise source. Each of the concerns are discussed below.

TABLE 5-4
TYPICAL SONIC BOOM OVERPRESSURE RANGES AND EQUIVALENTS

Overpressure	Common Equivalent
0.5 - 2	Pile driver at construction site
2 - 4	Cap gun or firecracker near ear
4 - 10	Handgun as heard at shooter's ear
10 - 14	Fireworks display from viewing stand

In 1986, an epidemiological study of health effects related to sonic booms was published. This was a statewide study of Nevada; chosen because sonic booms were carried out longer there than any place else in the U.S. It concluded that there was: "no convincing evidence to prove or disprove any relationship between exposure to sonic boom and adverse health phenomena."[120] A 1990 course on sonic boom effects concluded that there was no evidence of health effects and that hearing damage was "definitely not a problem."[121] The Committee on Hearing, Bioacoustics, and Biomechanics of the National Academy of Sciences/National Research Council has set an exposure limit of one impulse/day at 7.25 psf.[122] Based on the above, no health effects are anticipated.

Sonic booms cause human reactions similar to those produced by storm thunder. This can cause a startle effect. Startle effects involve involuntary movement (muscular reflexes). One concern with this type of reaction is the potential increase for accidents. In the anticipated range of two to three psf these may include eye blinking in about 50% of the subjects and arm/hand movements in about 25% of the subjects, but no gross bodily movements.[123] Another study found that this range will result in arm/hand movement in about 10% of the subjects but had no affect on automobile driver performance.[124] Although, as of 1990, there has been no known record of injury or trauma due to sonic booms, the potential for accidents remains.

Annoyance created by sonic booms is a function of boom intensity, number of booms per time period, attitude of the population, and the activity in which people were engaged in at the time of the boom. There is no precise relationship between the parameters. The results of various studies are presented below.

One study found that 10% of the subjects exposed to 10-15 booms per day were annoyed at an overpressure of one psf and that this reached nearly 100% at three psf.[125] However, people may be more sensitive, when exposed to numerous booms per day while prior experience with sonic booms (such as people who live on an Air Force base) seems to lower sensitivity. Other studies indicate that there is a wide range in estimating percent annoyed ranging from 10% to 70% at one psf and 55% to approximately 100% at three psf.[126]

Another measure of noise is provided by EPA's blast noise recommendation. The recommendation is to limit the level to 125 dB (unweighted) at sensitive receptors. Sonic booms may exceed this recommendation for an estimated two to 15 miles from the source.

As noted, the types of interference and activities people are involved in affect annoyance. Table 5-5 presents the results of a St. Louis study of annoyance involving multiple sonic booms.[127]

TABLE 5-5
EXAMPLES OF ANNOYANCE LEVELS FOR VARIOUS TYPES OF ACTIVITIES

Type of Interference/Activity	Percent Annoyed
House Shaking	38
Startled	32
Sleep	22
Rest	15
Conversation	10
Radio/television	7

In a similar study in Oklahoma City,[128] results were fairly comparable, except that a significantly higher portion of the subjects were annoyed when their houses were shaken (55% as opposed to 38%). However, EPA reported reversed order, for the last four activities, due to aircraft related annoyance.[129]

The preliminary findings in the most recently-published literature seem to indicate that: (1) people are more sensitive to sonic booms than previously thought and that existing community annoyance models do not capture this effect, and (2) people perceive sonic booms as more intrusive than aircraft noise at comparable levels. At an L_{dn} of 25 to 35 dBA the preliminary results indicate that 27% of the subjects, were a little annoyed; 22% were moderately annoyed, and 30% were very much annoyed. These people related sonic boom noise to "hearing big noisy trucks if you lived near an intersection or having a dog next door that regularly barks in the middle of the night."[130]

5.2.2 Noise Impacts on Wildlife

Effects on wildlife in natural situations from sonic booms produced by LVs are difficult to study or predict. In general, mammals and raptors do not panic when exposed to sudden intense noises, whereas waterfowl are more likely to startle and possibly injure themselves or their young when suddenly frightened.[131, 132]

Birds are most sensitive to noise in the 1,000 to 5,000 Hz range. This is far higher than frequencies associated with LV launches, especially sonic booms which have much of their energy below 100 Hz. Birds, however, may be startled by impulsive noises created by LV launches and the result may be flushing.[133] This may begin to occur at noise levels of 80 to 85 dBA. The effect will most probably be of short duration. That is, birds will return to nests, usually within minutes. Little egg damage has been recorded. Birds commonly nest and forage in and around airports and even under supersonic operating areas. No mortality, nor reduction in habitat usage has been observed within 800 feet of the Titan launch complex or within one mile of the Space Shuttle.[134]

Mammals seem to be less disturbed by noise than birds, but startle effects can occur. "Intense" sonic booms resulted in an alert and startle effect on bighorn sheep, while the endangered Sonoran Pronghorn was reported jumping and running.[135] However, there has been no "substantial effect on wildlife in or near the launch complex" for Space Shuttle or Titan IV launches.[136] Research by the U.S. Air Force on sonic boom effects on wildlife has found that:

> After fewer than five exposures, most animals become habituated to the noise and show little response. In research conducted on pronghorn antelope, Rocky Mountain elk, and bighorn sheep, exposure to sonic booms caused a light rise in heart rate after the initial disturbance. The startle responses decreased for subsequent booms and were soon less than those evoked by humans walking into animal pens, or bees and biting flies bothering the animals.[137]

Young sea lions and seals (pups), which are called pinnipeds, were tested to determine their physiological response to noise. The testing determined their temporary threshold shift. This is the temporary change in their ability to hear. It may be important as it could affect their ability to find food, social behavior, and survival. For example, the temporary threshold shift for Northern Elephant Seals lasted approximately 20 minutes at a pressure of 6.9 psf.[138] In harbor seals the temporary threshold shift lasted 90 minutes at a pressure of 7.2 psf.[139] The implications of these temporary threshold shifts have not yet been quantified.

Observations of pinniped and bird responses to Titan IV launches have been documented. These have taken place at Vandenberg AFB and in the Channel Islands, 30 to 40 miles from the launch pad at Vandenberg.

1. At Vandenberg AFB[140]

   - At an SEL of 99 dBA all 28 harbor seals moved toward the water, with 23 entering the surf.

   - At an SEL of 102 dBA all 41 seals rushed into the water. They began returning within 20 minutes and 75 percent returned within 90 minutes.

2. In Channel Islands

- At a sonic boom of 1.2 psf there was no behavioral changes in elephant seals. About 25 percent of California sea lions responded with a heads-up alert. None moved toward the water and returned to resting within 30 seconds. Furthermore, there was no response to light from launch, which lasted about two minutes.[141]

- In response to a Titan explosion (at maximum noise levels [not recorded]) 45 percent of the sea lions and 2 percent of the Northern fur seals rushed into the water. Approximately 15 percent of the sea lion pups were separated from their mothers for one to two hours.[142]

- At a sonic boom of 9 psf five of the six harbor seals rushed into water; 90 percent of the northern elephant seals became alerted, but none moved; and Brandt's Cormorants moved toward the water, but did not enter the surf.[143]

- At a sonic boom of somewhat less than 9 psf (no reading available) all California sea lions, not surrounded by elephant seals, rushed into the water. About 80 percent of the elephant seals became alerted and 25 of the 683 entered the surf.[144]

- At a sonic boom of somewhat less than above, twenty of twenty harbor seals fled into the water. Approximately 30 percent of the northern elephant seals became alerted.[145]

- Two hours after a sonic boom of 1.1 psf, three harbor seals were tested for temporary threshold shifts and permanent threshold shifts. "No detectable changes in seal's hearing occurred as a result of the launch" and the animals "appeared healthy and were in excellent condition.[146]

Several observations regarding fish response to sonic booms have been made. They range from no affect on fish eggs to stripped bass jumping out of tanks, resulting in death and dying of seizures in the water.[147]

Sonic booms from LV launches also impact underwater environments. These types of booms do represent a threat of physical and physiological impairment to marine mammals in the vicinity of the water surface, particularly if these mammals occur in the relatively restricted impact zone of the boom. Sonic booms from LVs may reach underwater depths of 0.25 to one kilometer in depth, and under repeated occurrence, might effect the migrating route and habitat choice of certain marine mammals.

Overall, it seems that most wildlife, excluding marine mammals, respond more adversely to visual impacts than to audio impacts. For example, wildlife has been known to return to their habitat once construction has ceased, even though operations have been quite noisy, such as near airport facilities.

5.2.3 Noise Impacts on Structures

Table 5-6 provides estimates of damage as a function of overpressure. Because LVs will possibly produce an overpressure in the two to three psf range, damage could be caused at exposed buildings to glass, plaster, roofs, and ceilings.[148] In well-built and maintained buildings, glass will receive the primary damage. Approximately one in 10,000 panes may be broken at an overpressure of four psf.[149] The amount of damage experienced will vary depending on the pre-existing condition of the structure subjected to the sonic boom.

The expected impact from sonic booms on structures resulting from commercial launches will vary for different flight paths from each launch facility. Sonic booms are propagated towards the ground only when the vehicle pitches over during its flight. Therefore, sonic booms will only impact those structures that lie on the ground below the flight path of the vehicle after it has pitched over. Flight paths may be altered to avoid overflight of sensitive structures. Mission specific and launch specific criteria determine the impact of sonic booms on structures and not the distance from which the structures are located from the launch site.

TABLE 5-6
POSSIBLE DAMAGE TO STRUCTURES FROM SONIC BOOMS [150]

Sonic Boom Overpressure Nominal (psf)	Type of Damage	Item Affected
0.5-2	Cracks in plaster	Fine; extension of existing; more in ceilings; over door frames; between some plaster boards.
	Cracks in glass	Rarely shattered; either partial or extension of existing.
	Damage to roof	Slippage of existing loose tiles/slates; sometimes new cracking of old slates at nail hole.
	Damage to outside walls	Existing cracks in stucco extended.
	Bric-a-brac	Those carefully balanced or on edges can fall; fine glass, e.g., large goblets can fall and break.
	Other	Dust fall in chimneys.
2-4	Glass, plaster, roofs, ceilings	Failures show which would have been difficult to forecast in terms of their existing local condition. Nominally in good condition.
4-10	Glass	Regular failures within a population of well-installed glass; industrial as well as domestic greenhouses.
	Plaster	Partial ceiling collapse of good plaster; complete collapse of very new, incompletely cured or very old plaster.
	Roofs	High probability rate of failure in nominally good state, slurry-wash; some chance of failures in tiles on modern roofs, light roofs (bungalow) or large area can move bodily.
	Walls (exterior)	Old, free standing, in fairly good condition can collapse.
	Walls (interior)	Inside ("Party") walls known to move at 10 psf.
Greater than 10	Glass	Some good glass will fail regularly to sonic booms from the same direction. Glass with existing faults could shatter and fly. Large window frames move.
	Plaster	Most plaster affected.
	Ceilings	Plaster boards displaced by nail popping.
	Roofs	Most slate/slurry roofs affected, some badly; large roofs having good tile can be affected; some roofs bodily displaced causing gale-end and will-plate cracks; domestic chimneys dislodged if not in good condition.
	Walls	Internal party walls can move even if carrying fittings such as hand basins or taps; secondary damage due to water leakage.
	Bric-a-brac	Some nominally secure items can fall, e.g., large pictures; especially if fixed to party walls.

5.3 Other Environmental Impacts of the Proposed Action

For each of the six environment types identified in Section 3.3, other potential environmental impacts of the preferred alternative are described in the following sections. Atmospheric and noise impacts have been previously addressed. Note that impacts from new construction are not within the scope of this proposed action.

5.3.1 Local Climate/Atmosphere

The characteristics of the local atmosphere that affect the air quality impacts of rocket launches include wind speed and direction, temperature, humidity and rainfall, atmospheric stability and mixing heights, and the topography of the area. The wind speed may affect the area over which the ground cloud may be dispersed. For higher wind speeds, the ground cloud may dissipate faster. For lower wind speeds, the ground cloud may disperse more slowly and therefore pose a hazard further downwind. In coastal environments, the prevailing winds may blow the ground cloud in the direction of the ocean.

The amount of rainfall and humidity may increase the likelihood and quantity of acid rain from HCl rained out of solid propellant rocket launch exhaust. This reduces the HCl load in all layers of the Earth's atmosphere. The mixing height and atmospheric stability will also affect the impacts of rocket launches. The more stable the atmosphere, the longer the ground cloud may hang over a particular area without much dispersion. Areas with great solar radiation tend to have less stable, more turbulent air atmospheres. Areas that are susceptible to inversion will tend to reduce the dispersion of the ground cloud. However, certain meteorological conditions can exist where the higher layer of air is warmer than the air below, creating an inversion layer. This warmer region is the mixing region which, because of its height in the atmosphere, tends to trap air pollutants. Topography affects the ground cloud in that flatter terrain generally decreases dispersion. Temperature is usually only a factor in influencing the evaporation rate of liquid pools.

In analyzing the six types of local climates examined in this PEIS, the primary factors that will influence dispersion include wind speed, atmospheric stability and wind direction, although other special factors may come into play. For the Mid-Atlantic Coastal Environment, the proximity of the site to the coast and the moderately strong winds from the south will blow some of the rocket exhaust out over the ocean. For launches during the day, the exhaust would be expected to dissipate relatively quickly. For the Southeastern Atlantic Coastal Environment, launches during the summer and fall may result in exhaust being blown inland, and the high seasonal rainfall will assist in raining out the HCl. Additionally, the prevailing winds during the winter months may disperse the exhaust over the ocean. High solar radiation will also help to disperse the exhaust because strong solar radiation heats air near the ground, causing the air to rise, thus generating large eddies and atmospheric turbulence that promote dispersion. In the Desert-Arid Environment, the high solar radiation will help with dispersion of exhaust at all altitudes, but the flat topography will reduce dispersion tendencies for ground level releases. HCl may be more of an atmospheric problem because of the little rain and humidity in this environment. In the South Central Pacific Coastal Environment, the Santa Ana winds in fall and winter will carry the exhaust to the ocean and will create high mixing heights that will trap most of the exhaust pollutants above the Earth's surface. In other seasons, the exhaust may disperse over land. In the Subarctic Environment, wind will be the main issue. The high winds from June to December will quickly disperse a ground cloud. The high precipitation will also assist in the HCl rainout. In the Sea-Launch Environment, the exhaust will be carried over the sea in the prevailing wind direction, and the HCl will be rained out. Further discussion and quantification of atmospheric loads is included in Section 5.1. and Appendix A.

5.3.2 Local Land Resources

The environmental impacts to land resources from the preferred alternative of licensing LVs for launches are mainly limited to impacts to soil from the formation of a launch ground cloud (from solid rocket motors) that produces acidic deposition. Soil impacts include temporary increases in available metals and in acidity. Amounts of HCl received by soils depends on the weather conditions and distance from the launch site. In non-saline type soils, increases in conductivity might be expected (e.g., calcium (Ca), potassium (K), sodium (Na), and zinc (Zn)) and decreases in phosphorus (P) and nitrogen as nitrate and nitrogen as ammonia. In saline type soils, increases in Ca, K, Na, Zn, and P might be expected, but not an increase in conductivity. Also in saline type soils, decreases in nitrogen as ammonia, but not nitrogen as nitrate might be expected.[151] Differences among potential local impacts are considered below.

Southeastern Atlantic Coastal Environment. Soils in this environment type tend to be well buffered (ability of a buffer solution to resist pH change upon addition of an acid or a base), and a cumulative decline in pH is not expected. This environment has both saline and non-saline soils.

Desert-Arid Environment. Soils in this environment type tend to be well buffered, and a cumulative decline in pH is not expected.

South Central Pacific Coastal Environment. The surface horizons of soils in this environment type appear to be high in both organic matter content and percent base saturation. High organic matter content and base saturation (extent to which the adsorption complex of a soil is saturated with alkali earth cations) result in the soil having a high buffering capacity. Therefore, limited impact is expected to the soils due to their high buffering capacity and the fact that the HCl expected from the dry launch system used in this region would be airborne in limited quantities and would be rained out over a limited area.[152]

Subarctic Environment. Soils in this environment tend to be well buffered because they have a high cation exchange capacity with an exchangeable H+ solution to H+ equilibrium of about 23,000:1 favoring H+. Therefore, no long-term measurable changes in soil acidity are expected.

Sea Environment. This environment does not contain soils in the path of the atmospheric deposition from the launch combustion products. Deposition to ocean surface waters is discussed below.

5.3.3 Local Water Resources

Surface water impacts include temporary increases in available metals and temporary increases in acidity. Levels of impacts to surface waters are highly variable spatially and temporally, and depend upon meteorological conditions at the times of launches.[153] Launch-related acid rain is created when fire and/or sound suppression system deluge water evaporates during a launch, scavenges HCl gas from the rocket exhaust, and forms hydrochloric acid droplets. Launch-related acid rain would not be an impact at launch site facilities using a dry launch duct (i.e., no deluge water system). Even with dry launch systems, the presence of coastal aerosols such as mists, fogs, or the marine layer could cause some molecular scavenging of water by HCl to occur. This process could produce acidic deposits, but on a very limited basis as compared to the levels associated with a wet launch system. In the event of an accident during ascent and possibly during an accident on the launch pad, rocket propellant containers would be ruptured and the propellants would burn explosively. Thus, it is possible for propellants to be spilled directly or released as a burning byproduct into local water resources (e.g., lakes, rivers) or more distant water resources (e.g., ocean). The extent of impacts depends on the type of propellant, the conditions of the accident, and the type of water resource affected. One category of liquid propellant, hydrazine propellants, are acutely toxic to aquatic life.[154] If released from an accident, hydrazine would either be oxidized in the air, would react and possibly ignite with the porous Earth, or would form soluble substances in water such as ammonia, methylamine and dimethyl amine and oxides of nitrogen.[155] These substances are toxic and injurious to plant and lower animal life if present in sufficient concentrations. Local impacts would be experienced.

Hydrocarbon propellants such as RP1 (kerosene) would form a film on the surface of the water. Depending on the quantity released and the surface area of the water body, the film could inhibit oxygen from penetrating the water body.[156] The film would dissipate within hours in large water bodies [157] but could adversely affect the aquatic ecology in small water bodies. Cryogens, such as liquid hydrogen and liquid oxygen represent extreme explosion potential. It is expected that the liquids released from an accident will explode. If, however, they are released directly into water, the cold temperatures of the cryogens would locally impact the water temperature. However, the liquid hydrogen and oxygen would rapidly volatilize and overall are not considered to be harmful to the environment.[158]

A hypergolic propellant such as nitrogen tetroxide is a toxic gas. In water, nitrogen tetroxide will react to produce nitric and nitrous acids. Ocean water is alkaline and will generally rapidly neutralize these acids. Consequently, it is not expected that the nitrogen tetroxide byproducts will have any lasting impacts on aquatic life. Solid rocket propulsion systems containing substances, such as ammonium perchlorate, are designed to burn the propellant completely. However, it is possible that chunks of the ammonium perchlorate in a binder matrix (e.g., PBAN) could fall into water bodies as unburned segments.[159] The toxicity of the ammonium perchlorate is based on its reactivity; ammonium perchlorate is a strong oxidizer and potentially explosive. As an anion it can act as a competitive inhibitor of biochemical reactions, such as iodide transport in the human thyroid.[160] However, it is expected that the ammonium perchlorate in a binder will dissolve slowly in the water with only very local impacts to marine life.[161] Small water bodies would be more adversely affected than large water bodies.

Differences among potential local impacts are considered below.

<u>Mid-Atlantic Coastal Environment.</u> Surface waters in this environment type tend to be well buffered, and a cumulative decline in pH is not expected.

<u>Southeastern Atlantic Coastal Environment.</u> Surface waters in this environment type tend to be well buffered, and a cumulative decline in pH is not expected.

<u>Desert-Arid Environment.</u> No surface watercourses exist in the immediate vicinity of the local environment and therefore no impacts to this surface water resources would occur in this environment type.

<u>South Central Pacific Coastal Environment.</u> Water quality data indicate that the surface water bodies in this region have high total hardness with high levels of cations such as Ca, Mn, and Na. In the event that rain water absorbs HCl which might in turn then be deposited on the water, the natural buffering capacity of the streams would result in negligible or no change in water quality.[162]

Subarctic Environment. Based on the buffering capacity and volumes of the surface waters in this environment, small pH changes could result from atmospheric deposition of HCl.

Sea Environment. No adverse effects from acid deposition are anticipated from the preferred alternative on the open-ocean environment, because the volume of ocean water and the flushing effect would quickly dilute any pH changes.

5.3.4 Local Biological Resources

Flora in the vicinity of the launch site may be affected by the launch exhaust products from near-field sources, far-field depositions, or from combustion products associated with catastrophic events. These impacts would be a function of the weather, the behavior of the ground cloud, the location of the biota relative to the diffusing cloud mass, and the type of vehicle launched. At high concentrations, effects on flora could range from injury to leaves or flowers to leaching of nutrients through the leaves. Vegetation changes from repeated near-field deposition include loss of sensitive species, decline in shrub cover, and increasing bare ground. However, affected vegetation would be expected to recover, based on deposition impacts on vegetation from Space Shuttle launches.[163] Impacts to wetlands could also occur from acid deposition depending on how often the wetlands are inundated with water and the amount of water. Wildlife impacts from repeated near-field deposition can include fish kills and occasional mortality of terrestrial fauna. Launches present the potential for acute impacts to fish and wildlife in the vicinity of the launch pad resulting from noise, blast debris, heat, and toxic chemicals (primarily HCl from solid propellants). Chronic impacts could result from subtle alterations in habitat and potentials for bioaccumulation of pollutants that may be released into the environment. However, a study of the impact of ten years of Shuttle launches on the local biota, soil, and water has not borne this out.[164]

Other possible impacts to biological resources could be lighting associated with facilities at the launch site or other launch-related physical disturbances to the environment. For example, endangered sea turtle hatchlings have been disoriented by exterior launch site lighting, moving inland rather than seaward and consequently suffering increased mortality.[165]

Fires and explosions, though highly improbable events, also constitute potential biota-impacting accidents. Specific effects would depend on the location and extent of the accident and the resultant primary effects (changes in noise, air quality, water quality, and thermal surroundings). Fires could begin near the launch site and burn off special habitat unless immediately contained. Subsequent natural re-growth would occur, but could take several years depending on the extent of the fire damage. Fire control measures would reduce this extent. Proven fire fighting methods would be employed in all appropriate situations. Explosions of highly-stable solid rocket motors are highly unlikely, but may occur in rare situations. The environmental impacts would most likely be minimal. For example, preliminary results of biological monitoring after the January 17, 1997 Delta II LV failure indicate that there were no discernible effects on the scrub jay population and that the overall population of Southeastern beach mice actually increased in areas affected by the explosion.[166]

One concern is that a higher launch rate in the future could produce long term effects on biota not exhibited under the current infrequent launch rate schedules. For instance, even if HCl is neutralized by alkaline soils, an excess of chloride will remain in the soil. This excess may be harmful to plant life over the longer term. However, several factors suggest that significant additive effects on vegetation would not occur at current or future commercial launch sites, including: (1) minimal effects are expected per launch; (2) susceptible plant parts (e.g., leaves, flowers) are short-lived, limiting the number of launches to which they are exposed; and (3) HCl gas dissipates after a launch, and would not accumulate in the area due to the high buffering capacity of the soil. Similarly, several factors suggest that significant additive effects on wildlife would also not occur, including: (1) minimal effects are expected per launch; and (2) no far-field cumulative effects on wildlife were observed to be caused by the 43 Space Shuttle launches over a ten year period.[167] However, high launch rates could displace sensitive bird or waterfowl species in some environments, requiring monitoring for potential effects in the future.

Mid-Atlantic Coastal Environment. Diverse animal species would be expected in this environment type with somewhat less diverse plant species. Many terrestrial and aquatic species may live in this environment. Few plants are able to thrive in the beach communities of this environment type, but more variety may be found in dunes, swales, maritime forests, and marshes. Examples of sensitive species in this environment type might include upland sandpipers, American bald eagles, peregrine falcons, piping plover, gull-billed tern, and Wilson's plover. While some adverse impacts could be expected in the immediate launch area, local wildlife impacts are anticipated to be minimal and manageable overall due to the infrequency and short duration of launches and the tendency for wildlife to scatter and then return after launches. Impacts on waterfowl populations in this environment might be of potential concern because, as stated earlier, waterfowl are more likely to injure themselves or their young when exposed to sudden noise. Monitoring of waterfowl and bird populations would be appropriate in this environment. NASA has determined that current rocket programs in this environment type "are not nearly as intrusive to the plover habitat as predators and recreational use."[168]

Southeastern Atlantic Coastal Environment. Diverse biological species would be expected in this environment type. Examples of sensitive species in the dune and strand communities are herbs with thin leaves and some shrubs with succulent leaves. Shrubs vary in sensitivity, but most grasses and heavily cutinized plants tend to be resistant. Wildlife impacts from repeated near-field deposition might include fish kills and occasional mortality of terrestrial fauna. However, local wildlife impacts are anticipated to be minimal and manageable overall due to of the infrequency and short duration of launches and the tendency for wildlife to scatter and then return after launches.[169] For example, since 1995, pre-launch and post-launch surveys of nine Atlas launches have been performed at a government launch site in this environment type that has been in use since 1962. No animal or aquatic species mortality has been observed in these surveys. Furthermore, impacts on vegetation are confined to two small areas (approximately 25 to 50 meters wide and 30 to 150 meters in length) immediately adjacent to the two pads.[170]

Desert-Arid Environment. Limited, but in some cases relatively unique, species and habitats would be expected in this environment type. Examples of sensitive species in the desert-arid environment are the desert tortoise and certain endangered or threatened plants found in creosote brush scrub. While some adverse impacts could be expected in the immediate launch area, local wildlife impacts are anticipated to be minimal and manageable due to of the infrequency and short duration of launches, the tendency for wildlife to scatter and then return after launches, and the generally low number of wildlife populations in this environment. Monitoring and mitigation plans would be appropriate, particularly for the desert tortoise.

South Central Pacific Coastal Environment. Diverse biological species would be expected in this environment type. Examples of sensitive species in this environment type include the desert tortoise, Mohave ground squirrel, and endangered or threatened plant species that might be found in Joshua Tree woodland, mesquite woodland, creosote bush shrub, arid phase saltbush scrub, and halophytic phase saltbush scrub. Observation of plant communities and wildlife at active launch sites in this environment type indicate that plants and wildlife are able to thrive in the extreme, near-field of launch area, even under conditions associated with relatively large launch vehicles using water sound suppression systems. Thus, exposures during routine operations are expected to be low and effects on biota are expected to be minor and short-term in this environment type.

Subarctic Environment. This environment may include a rich variety of wildlife, including a broad range of bird and waterfowl species (terrestrial and/or marine-oriented), terrestrial mammals (e.g., bats, hares, squirrels, voles, beaver, fox, otter, bear, and goat), marine mammals (e.g., large to small-sized cetaceans and pinniped species), and freshwater and anadromous fish. Examples of sensitive species in this environment type include the Steller sea lion, fin whale, humpback whale, Steller's eider, and bald eagle.

It is possible that fish could be impacted by rapid increases of hydrochloric acid from drainage of deluge water in nearby water bodies in this environment type, if water sound suppression systems are used. However, due to the characteristics of water bodies in this environment type (high rainfall/flushing rates, short steep streams with small drainage areas), long term effects to native game and no-game fish in these streams would not be anticipated. However, monitoring of nearby surface water bodies and fish populations would be appropriate.

It is anticipated that most birds would be frightened away by the noise of launches and thus would not come into contact with launch plumes. There is currently no data available about the exact effects exposure to such low levels of hydrochloric acid would have on birds. However, it is possible that birds flying through the launch cloud in this environment type could experience minor eye and respiratory irritation from concentrations of hydrochloric acid. Because of this, monitoring of bird populations would be appropriate.[171]

Overall, minor damage to vegetation and wildlife in the immediate vicinity of the launch pad could occur in this environment type. However, local wildlife impacts are anticipated to be minimal and manageable because of the infrequency and short duration of launches, the characteristics of water bodies in this high rainfall environment, and the general tendency for all wildlife to scatter and then return after launches.

Sea Environment. Limited and geographically dispersed biological species would be expected in this environment type. No environmental effects are anticipated from the preferred alternative in the open-ocean environment. The water, atmospheric, and biological resources (including fishing zones) are not expected to be impacted or would be negligibly impacted due to the extreme remoteness of this type of launch environment.[172]

5.3.5 Marine Mammals Strike Probability Analysis

Normal operating procedure for ELV flights is the separation and jettison of expended stages, motors, or fairings over the ocean. Reusable launch vehicles are designed so that expended stages return to the launch site (or alternate emergency site), land, and are recovered. Thus, this type of LV is not considered further for this analysis.

There is a remote possibility that jettisoned or separated motors, stages or fairings from an LV could strike a marine mammal when it enters the ocean during nominal flight operations. The probability of a strike has been approximated using conservative assumptions and simulation analysis with high end

CeTAP cetacean density data for the mid-Atlantic Ocean and ship survey data in California waters for the Pacific Ocean. The results of this analysis indicate that there is extremely little chance of an LV component hitting a marine mammal. The methodology and results of the analysis are presented in Appendix B. As detailed in the appendix, less than 0.5 mammals per year are expected to be hit, even when all launch activity is summed, and a summation is done across all species over both oceans.

5.4 Socioeconomic Effects of the Preferred Alternative

Development and growth of the commercial LV industry will have a beneficial economic impact. Jobs associated with the commercial LV industry tend to be technology-based and require highly skilled workers with specialized skills and education. The creation of jobs of this caliber has secondary positive economic effects on local communities from increased personal income and the associated tax base. Additional workers create a need for more services, which in turn creates additional jobs. Any impacts associated with workforce increases at a new commercial launch site, including the ability of communities to provide needed infrastructure support (e.g., roads, schools), would be assessed in site-specific NEPA documentation.

The impact on the national economy would probably be small, but is dependent on the success of private ventures. More difficult to predict, but likely, positive impacts are the technology transfer from commercial space technology to other economic sectors (e.g., manufacturing and consumer goods). If the United States retains a leadership position in space technology, the country will likely also gain a competitive advantage in other technology-based markets.

5.5 Environmental Justice Effects of the Preferred Alternative

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations, requires federal agencies to identify and address disproportionately high and adverse human health or environment effects of federal programs, policies, and activities on minority and low income populations. A Presidential Memorandum that was issued concurrently with EO 12898 specifically states that NEPA is one of the tools for addressing these issues. “Each agency must analyze the environmental effects, including human health, economic, and social effects, of its actions, including their effects on minority communities and low-income communities, when such analysis is required by the NEPA.” AST considers environmental justice one of several key areas considered and assessed for impacts during the environmental review process.

Although each community is unique, there are several determination procedures that are common to most environmental justice assessments. It is important that one first identify whether the geographical area being considered qualifies as a low-income or minority-based area. This can be accomplished by analyzing the most recent census data for the subject location (a census block group). The US Bureau of Census maintains census data based upon racial classifications and income levels. The racial data are classified into five racial types: white, black, Hispanic, American Indian/Eskimo/Aleut, and Asian/Pacific Islander. Income data are determined by the percentage of houses within the geographical area of consideration that fall below the mean poverty level (a four person family earning $12,674 or less in 1990). Within each census block group, percentages of minority and low-income communities can then be calculated.

Once the determination is made whether the area in question is populated by low-income or minority individuals, the next determination that must be made is whether the action has disproportionately high and adverse human health or environmental impacts to the community. Environmental justice compliance requires, first, that a determination be made that there are significant and adverse impacts, and, second, that those impacts disproportionately affect the low-income or minority communities. If a determination is made that a particular action will adversely affect a minority or low-income community, the recommended action by the United States Environmental Protection Agency is to have as much community involvement as possible early in the project scoping process. Both EO 12898 and the Presidential Memorandum emphasize the need for public participation and access to information. The Presidential Memorandum states that each federal agency shall provide opportunities for community input in the NEPA process, including identifying potential effects and mitigation measures in consultation with affected communities and improving the accessibility of meetings, crucial documents, and notices.

Specific information about a local community would have to be obtained to fully assess whether environmental justice issues are a concern near a current or future commercial launch site. However, the following subsections suggest possible populations of concern for each generic environment. These populations should be analyzed for disproportionate environmental justice impacts during the environmental review of licensing for commercial launch operators. Because this analysis assumes that the preferred alternative will result in *positive* socioeconomic effects, including maintaining or increasing current employment levels in the U.S. space industry, it is assumed that these positive effects will at a minimum not produce disproportionate *negative* impacts on minority racial, ethnic, or economically-disadvantaged populations.

<u>Southeastern Atlantic Coastal Environment.</u> Environmental justice populations of concern that may live in communities in the southeastern Atlantic coastal environment include Native Americans, Hispanic Americans, African Americans, and economically-disadvantaged populations.

<u>Southwestern Desert-Arid Environment</u>. Environmental justice populations of concern that may live in communities in the southwestern desert-arid environment might include Native Americans, Hispanic Americans, African Americans, and economically-disadvantaged populations.

<u>South Central Pacific Environment</u>. Environmental justice populations of concern that may live in communities in the south central Pacific environment might include Native Americans, Hispanic Americans, Asian Americans, African Americans, and economically-disadvantaged populations.

<u>Subarctic Environment.</u> Environmental justice populations of concern that may live in communities in the subarctic might include Native Americans and economically-disadvantaged populations.

<u>Sea Environment.</u> Environmental justice populations of concern that may live in communities in the sea-launch environment include international minority ethnic and racial populations and economically-disadvantaged populations.

6. Potential Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

In general, because the proposed alternative of preferentially licensing more environmentally-friendly propellant LVs for launches results in less HCl, Al_2O_3, NO_x, and Cl emissions and less overall launches in the U.S., potential effects in the local and global climate/atmosphere, local land resources, local water resources, local biological resources, and on marine species in the Atlantic and Pacific Oceans, would be correspondingly reduced across all environment types. Socioeconomic effects would be negative, as a result of the anticipated exodus of launches utilizing only solid propellant in the troposphere and stratosphere to outside the U.S.

6.1 Potential Environmental Impacts to the Atmosphere of the More Environmentally-Friendly Propellant Combinations Alternative

Potential impacts in the atmosphere from this alternative were examined in the troposphere and stratosphere. No change from this alternative was estimated relative to the preferred alternative for effects in the mesosphere and ionosphere, because the alternative does not affect emissions in those regions of the atmosphere.

As stated earlier in the description of this alternative in Section 2, air emissions from LVs are determined mainly by propellant type. The environmentally harmful chemicals emitted to the atmosphere vary by the type of propellant used. For example, all propellant systems, except those using purely LOX-hydrogen systems, produce CO_2, which is a greenhouse gas. Greenhouse gas emissions in the troposphere and stratosphere are of concern because they contribute to global warming by trapping re-radiated energy in the atmosphere (e.g., water vapor, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrolfluorocarbons, and perfluorinated carbons). Hybrid and LOX-RPI propellant systems produce more CO_2 than solid propellant systems, however, they emit less NOx than systems using hypergolic propellants. Only solid rocket motors (SRMs) produce tropospheric and stratospheric emissions of HCl and Al_2O_3. HCl is a toxic gas, which is defined by EPA as a Hazardous Air Pollutant. Al_2O_3 is a particulate that can serve as a site for atmospheric reactions depleting ozone. Emissions of HCl and Al_2O_3 are perceived as more significant, immediate environmental threats than the greater amount of CO_2 emissions produced by hybrid and LOX-RP1 propellant systems (see Appendix A).

Thus, for this analysis, the alternative option of "More Environmentally-Friendly Propellant Combinations" was defined as consideration of vehicles that produce less harmful tropospheric and stratospheric air emissions of HCl and Al_2O_3 for preferential licensing. Because these emissions are clearly linked to a single propellant system (i.e., SRMs), an alternative to the preferred alternative is to preferentially license LVs using no SRMs or combinations of SRMs and liquids in the troposphere or stratosphere, excluding LVs only powered by SRMs in the troposphere or stratosphere. While it may be environmentally preferable to limit all SRM usage, this alternative is not feasible because current technology requires a combination of liquids, cryogenics, and SRM propellants to launch a rocket into geosynchronous orbit. Therefore, preferentially licensing of rocket propellants that do not utilize any SRMs would exclude all larger, three-stage GEO rockets. Furthermore, conclusive data and analysis regarding the specific impacts of emissions from multi-propellant launch vehicles (e.g., liquid and solid combinations) currently do not exist. Because the environmental impacts related to combined emissions of multi-propellant LVs have not been adequately characterized at this time, this analysis relies on existing, available data on emissions from single propellant systems. Ongoing U.S. Air Force and industry research in this area may alter the future understanding of the cumulative atmospheric impacts of multi-propellant LVs and the relative atmospheric impacts of different types of propellant systems.

Preferentially licensing those rockets that are not solely propelled by SRMs would reduce the total number of U.S. commercial launches projected from 1998 through 2009 to 134. The number of launches using liquid, liquid/solid, or hybrid propellant systems is assumed to remain the unchanged under this alternative. Thus, the total number of commercial, AST-licensed launches in the U.S. (i.e., programmatic launches) would decrease substantially under this alternative. It was assumed that the decrease in U.S. commercial launches using only solid propellants would be compensated for by an increase in these launches elsewhere in the world.

Again, as stated earlier, HCl emissions from SRMs are of primary concern because of the large quantity released and because HCl is a source of chlorine. Because HCl can deplete ozone it must be photolyzed to release the Cl. Some of the HCl is mixed back into the troposphere and rained out before it is photolyzed. Thus, it has a chance to destroy ozone. Beside gases, SRMs release particulates, Al_2O_3, soot, and ice. Attempts to determine the distribution and effect on ozone depletion of Al_2O_3 have been limited and therefore the current models are based upon homogenous gas phase chemistry. Such particulates act as a site for the ozone depleting reaction, but the significance of this role is unclear. Heterogeneous chemistry (which accounts for particulates, plume temperature and afterburning of fuel-rich exhaust) is not included in this PEIS, due to limited data and modeling available to date. However, future analysis of rocket launches using heterogeneous chemistry could alter the understanding of potential impacts of LVs on stratospheric ozone-depletion.

The specific HCl input to the stratosphere from rocket exhaust can be estimated if the HCl amount and its time-dependent releases along the ascent are known. Using the number of launches estimated in Section 2.0, but eliminating all launches using solely solid propellant systems in the troposphere and stratosphere, the emission load of HCl in the stratosphere for all U.S. commercial LV launches from 1998 through 2009 (a period of 12 years) is approximately 905 tons and additional free Cl load is 12 tons. This averages to approximately 76 tons of HCl and Cl load to the stratosphere from U.S. commercial LV launches per year. (See Appendix A, Emission/Afterburning Products and Loads for a detailed methodology determining numbers and emissions loads.) In comparison, under the preferred alternative, the emission load of HCl in the stratosphere for all U.S. commercial LV launches from 1996 - 2005 is approximately 5,024 tons and additional free Cl load is 67 tons. This averages to approximately 424 tons of HCl and Cl load to the stratosphere from U.S. commercial LV launches per year.

Accidents on the launch pad. Emissions of concern resulting from potential accidents on the launch pad would be reduced under this alternative because rockets using solid propellant systems would no longer be licensed. Thus, open burning of all solid propellants would not be an issue, thereby avoiding the potential for a release of approximately 3,200 kg (3.5 tons) of HCl emissions; 3,520 kg (3.9 tons) of CO_2 emissions; 2,720 kg (3 tons) of CO emissions; 6,434 kg (7 tons) of Al_2O_3 emissions; and 550 kg (0.6 tons) of NO_x emissions. (These emission estimates are based on the CASTOR 120™ boosters and approximately 49,033 kg (108,100 lbs) of propellant; these avoided emissions may be higher with vehicles with larger solid rocket motors.) Furthermore, the potential for HCl to combine with moisture in the air and form hydrochloric acid during an accident would also be avoided. Similarly, accident-related excess CO and NO_x emissions could also potentially impact the air quality or local acid rain in the area of a launch accident for that day, especially if the area is nonattainment and does not meet the National Ambient Air Quality Standards for CO, NO_x or ozone.

Accidents where a flight safety system is activated may result in the burning of remaining propellant in the atmospheric layer where the termination occurs. If the accident occurs in the troposphere, all of the propellant may burn. Emissions from such accidents, especially CO_2, may be greater than an accident on the launch pad and may affect global warming. Thus, under this alternative, potential emissions from an accident where a flight safety system is activated and solid propellant is consumed would be avoided for a subset of launches that are assumed would no longer occur in the U.S.

6.2 Noise Effects of the More Environmentally-Friendly Propellant Combinations Alternative

The preferred alternative found limited support for evidence of noise impacts from licensing commercial LVs. If this alternative had any noise impacts, these impacts would be in the direction of producing even less noise impacts than the preferred alternative. This alternative would reduce the impact of launch noise in the aggregate because the number of commercial LV launches from within the continental United States would be greatly reduced.

6.3 Land Resources Effects of the More Environmentally-Friendly Propellant Combinations Alternative

Implementing the "more environmentally-friendly propellant combinations" alternative would reduce impact on the soils from commercial launches in the vicinity of launch pads at U.S. launch sites. Space Shuttle and other government launches would still have an impact on soil pH. However, the cumulative effects would not be as great due to fewer commercial launches involving only solid propellant. The more environmentally-friendly propellants would not use solids and therefore the impacts caused by the ground cloud to the local vegetation and soils would not be as significant. This alternative would reduce the impact on land resources because the number of commercial LV launches from within the continental United States would be greatly reduced.

6.4 Water Resources Effects of the More Environmentally-Friendly Propellant Combinations Alternative

The prospect of additional local water impacts near a commercial launch site from licensed commercial launches would be reduced. Additionally, coastal waters, that could be affected in the event of an accident, would experience reduced impacts. This alternative would reduce the impact on water resources because the number of commercial LV launches from within the continental United States would be greatly reduced.

6.5 Biological Resources Effects of the More Environmentally-Friendly Propellant Combinations Alternative

Vegetation changes from the ground cloud at launch would be reduced as well as wildlife impacts from launch activities. However, the increased demand for launch sites could lead to construction of launch sites outside the U.S.[173] These launch sites could potentially have a significant impact on biodiversity if they are sited on or near endangered or biologically fragile ecosystems (i.e., rain forest, habitats of endangered species). The U.S. has a history of operating launch sites while effectively protecting native species. For example, Kennedy Space Center manages 140,000 acres of protected beach, wetland, and sub-tropical ecosystems with 23 threatened or endangered species living in the environs. Even if launch sites are not located on or near fragile ecosystems, the impact of building facilities that launch space vehicles while U.S. launch sites go underutilized is not an effective use of the world's natural resources. Finally, the probability of jettisoned ELV sections (e.g., spent SRMs, payload fairings) making direct contact with a marine species would remain remote. This alternative would reduce the impact on biological resources because the number of commercial LV launches from within the continental United States would be greatly reduced.

6.6 Socioeconomic Effects of the More Environmentally-Friendly Propellant Combinations Alternative

Development and growth of the commercial LV industry would have a beneficial economic impact; limiting this development and growth by preferentially licensing a subset of LVs would reduce the magnitude of this beneficial impact relative to the preferred alternative.

6.7 Environmental Justice Effects of the More Environmentally-Friendly Propellant Combinations Alternative

Because this is a programmatic EIS, analysis of environmental justice effects of this alternative are general and not site-specific in nature. Thus, environmental justice effects within the scope of this analysis are related to the socioeconomic effects. Because this analysis assumes that this alternative will result in *positive* socioeconomic effects (although less relative to the preferred alternative), including maintaining or increasing current employment levels in the U.S. space industry, it is assumed that these positive effects will at a minimum not produce disproportionate *negative* impacts on minority racial or low-income populations.

7. Potential Impacts of the No Action Alternative

The no action alternative would negatively impact the national security and foreign policy interests of the United States. Some U.S. government payloads have been launched by the U.S. commercial space launch industry. Therefore, if access to commercial LVs is not available, the overall limit in available capacity could conceivably impact the U.S. government's ability to launch needed payloads and thereby negatively affect programs that rely on access to space. Additionally, parties that had planned to launch from U.S. launch sites would be forced to find alternatives, potentially exposing sensitive technologies to countries with competing economic and security interests.

Under the no action alternative it is assumed the same number of worldwide commercial LV launches would take place. However, were AST to cease issuing licenses for launches by U.S. companies, the launches would take place from foreign locations. Without access to commercial launches in the United States; it is likely that other countries with existing space launch programs (e.g., France, Russia, China, Canada) would substantially expand their programs to accommodate the excess demand. It is possible that other countries would initiate launching of commercial LVs, resulting in no net gain to the global environment.

7.1. Potential Environmental Impacts to the Atmosphere of the No Action Alternative

It is possible that if no commercial LV launches could take place from the U.S., then fewer LVs would be launched overall worldwide (unless existing foreign launch programs could expand rapidly to accommodate increased launch requirements). This would result in an overall decrease globally of rocket emissions that potentially affect the atmosphere.

However, based on the comparison of capacity and propulsion systems, the transfer of launches from U.S. LVs to foreign LVs could cause an increase in atmospheric emissions overall. Local effects, such as acid rain and tropospheric ozone would happen outside the U.S. However, global warming potential and stratospheric ozone depletion would remain essentially the same based on an equal number of launches. In a similar manner, any potential impacts to the F layer of the ionosphere would occur regardless of where an LV was launched. This alternative would reduce the impact on atmospheric resources because the number of commercial LV launches from within the continental United States would be greatly reduced.

7.2. Noise Effects of the No Action Alternative

The prospect of noise impacts and sonic booms from the launch and flight of commercial LVs at current or future commercial U.S. launch sites would be reduced.

7.3. Land Resources Effects of the No Action Alternative

If no licensed commercial LV launches occurred, there would be no impact on the soils from commercial launches in the vicinity of launch pads at U.S. launch sites. Space Shuttle and other government launches would still have an impact on soil pH, but the cumulative effects from these launches, absent the commercial launches, would not be as great. This alternative would reduce the impact on land resources because the number of commercial LV launches from within the continental United States would be greatly reduced.

7.4. Water Resources Effects of the No Action Alternative

The prospect of additional local surface and groundwater impacts near a commercial launch site from licensed commercial launches would be eliminated. Additionally, coastal waters, and associated wetlands that could be affected in the event of an accident, would no longer be potentially impacted. This alternative would reduce the impact on water resources because the number of commercial LV launches from within the continental United States would be greatly reduced.

7.5. Biological Resources Effects of the No Action Alternative

Vegetation changes from the ground cloud at launch would be reduced as well as wildlife impacts from launch activities. However, the increased demand for launch sites could lead to construction of launch sites outside the U.S.[174] These launch sites could potentially have a significant impact on the world-wide biodiversity if they are sited on or near endangered or biologically fragile ecosystems (i.e., rain forest, habitats of endangered species). The U.S. has a history of operating launch sites while effectively protecting the native species at the same time. For example, Kennedy Space Center manages 140,000 acres of protected beach, wetland, and sub-tropical ecosystems with 23 threatened or endangered species living in the environs. Even if launch sites are not located on or near fragile ecosystems, the impact of building facilities that launch space vehicles while U.S. launch sites go underutilized is not an effective use of the world's natural resources. The probability of jettisoned ELV sections (e.g., spent SRMs, payload fairings) making direct contact with a marine species would remain remote. This alternative would reduce the impact on biological resources because the number of commercial LV launches from within the continental United States would be greatly reduced.

7.6. Socioeconomic Effects of the No Action Alternative

The no action alternative would have negative socioeconomic impacts by forcing all payloads currently planned for commercial launch in the U.S. to use foreign launch vehicles. As a result, U.S. jobs would be lost to foreign entities to support their launch activities and programs. It is also *possible* that U.S. telecommunications companies and other U.S. space users would be given lower priority in launching satellites, if foreign entities find a market advantage in preferentially launching their own satellites. This in turn could create a potential for scheduling problems and loss of competitiveness for the U.S. in the global technology market.

The U.S. economy would not enjoy the full potential benefits of high-technology jobs or multi-billion dollar revenues derived from the commercial space launch industry. Companies directly involved in providing commercial launch services would no longer be able to operate in that capacity and would be significantly affected. Companies that produce rocket engines or vehicle components could also experience a decline in revenue. The impact to hardware producers would be less severe than for service providers because: (1) the revenue stream from continued military launches would likely continue; and (2) the opportunity for sales of propulsion units and vehicle components overseas could improve because foreign launch providers would need more vehicles to meet the demand from the increase in U.S. payloads seeking their launch services.

Closing the commercial LV private sector would both foreclose potential domestic economic benefits and reduce U.S. international competitiveness. If technological advances are achieved during the development and use of foreign LVs, foreign enterprises would gain further advantages in marketing these new goods and services. Thus, foreign economies could possibly be stimulated, while the U.S. would lag behind, both economically and technologically.

7.7. Environmental Justice Effects of the No Action Alternative

Because this is a programmatic EIS, analysis of environmental justice effects of the no action alternative must be general and not site-specific in nature. Thus, environmental justice effects within the scope of this analysis are related to the socioeconomic effects noted in the previous subsection. Because the no action alternative would have negative socioeconomic impacts that may result in a loss of U.S. jobs to foreign entities, it is possible that economically-disadvantaged or minority ethnic or racial populations may suffer some disproportionate affects of these job losses.

8. POTENTIAL CUMULATIVE IMPACTS

This section analyzes the cumulative impacts of commercial LVs combined with all other rocket launches worldwide. All other rocket launches, or non-programmatic launches, include U.S. government launches, foreign commercial launches, and foreign government launches. The emissions loads from all rocket launches to the troposphere, stratosphere, mesosphere and ionosphere will be evaluated. The cumulative impacts on land, water, and biological resources are highly dependent on site-specific characteristics, and therefore are not addressed in this PEIS.

This PEIS, as stated in the definition of preferred alternative, assesses the potential impacts of 436 commercial LV (programmatic) launches between 1998-2009. AST has estimated that worldwide commercial LV launches will be 711 between 1998-2009, thus 275 additional commercial LVs (non-programmatic) will be launched at foreign launch sites. Other non-programmatic launches, such as U.S. government launches and foreign government launches, have been estimated from various sources (See Appendix A) to be 342 and 750 launches, respectively. This results in a total of 1,092 government launches between 1998-2009. For the purpose of this PEIS in evaluating cumulative impacts, it is estimated that there will be 1,803 rocket launches worldwide, including programmatic and non-programmatic, between the years 1998-2009. (See Appendix A for further information.)

Preferentially licensing rockets that are not solely propelled by SRMs would reduce the total number of U.S. commercial launches projected from 1998 through 2009 to 134. The number of launches using liquid, liquid/solid, or hybrid propellant systems was assumed to remain unchanged under this alternative. Thus, the total number of commercial, AST-licensed launches in the U.S. (i.e., programmatic launches) would decrease substantially under this alternative. It was assumed that the decrease in U.S. commercial launches using only solid propellants would be compensated for by an increase in these launches elsewhere in the world. Under the no action alternative, there would be no commercial launches in the U.S.

Many studies have been done on the cumulative environmental effects of rocket launches worldwide. The American Institute for Aeronautics and Astronautics convened a workshop to identify and quantify the key environmental issues that relate to the effects on the atmosphere of rocket launches. The conclusion of the workshop, based on evaluation of scientific studies performed in the U.S., Europe, and Russia, was that the effects of rocket propulsion on stratospheric ozone depletion, acid rain, toxicity, air quality, and global warming were extremely small compared to other anthropogenic impacts. The workshop recommended that further analysis needed to be done on the effects of rocket propulsion on the atmosphere to account for heterogeneous chemistry (i.e., to better account for particulates, aerosols, soot and ice emissions).

8.1. Potential Environmental Impacts in the Atmosphere

8.1.1. Troposphere

The main cumulative impacts to the troposphere would result from the impacts of the emissions of HCl and NO_x during the rocket's ascent. NO_x is a tropospheric ozone precursor. U.S. commercial LVs generally do not use hypergols in the first stage and therefore emit very small quantities of NO_x. Therefore, the impacts of the NO_x emissions would be insignificant. Table 8-1 summarizes the world total emission loads to the troposphere. The carbon monoxide produced by the rocket's propulsion systems is assumed to react with oxygen in air to produce carbon dioxide in the high temperatures of the exhaust plume. The impacts of these specific emissions are discussed below. Overall, the cumulative impact of all of these emissions loadings is relatively insignificant compared with industrial and natural emissions loadings to the troposphere. As the table shows, hydrogen chloride and chloride emissions to the troposphere for non-programmatic launches are more than four times greater than the programmatic emissions.

TABLE 8-1

SUMMARY OF PROGRAMMATIC AND NON-PROGRAMMATIC EMISSION LOADS FROM ROCKETS TO THE TROPOSPHERE (TONS) FROM 1998 - 2009

	HCl	Al_2O_3	CO_2	H_2O	N_2	Cl	NO_x	CO
Programmatic								
US Commercial	5024.3	9048.4	24744.1	10141.3	2001.1	66.99	0	0
Non-Programmatic								
US Government Launches	13108.3	23705.9	35151.7	28087.7	5240.5	174.8	0	0
International Commercial Launches	2504.0	4523.4	15424.4	8110.6	936.9	33.4	9215.4	0
Foreign Government Launches	6801.9	12288.2	42297.1	22101.2	2552.6	90.7	24923.4	0
Total Non-Programmatic	22414.2	40517.5	92873.2	58299.5	8730.1	298.9	34138.7	0
Total Programmatic and Non-Programmatic	**27438.5**	**49565.9**	**117617.3**	**68440.8**	**10731.1**	**365.9**	**34138.7**	**0**

Acid Rain. Solid rocket motors produce HCl in the exhaust plume that is released into the troposphere. Although local acid rain from rocket exhaust is common, the global contribution of rocket exhaust to acid rain is very small. On a global scale, HCl produced by all programmatic/non-programmatic rocket launches is less than 0.001 percent of the total HCl production from the oceans alone and is less than 0.15 percent of anthropogenic sources, such as coal burning power plants. It is estimated that launching nine Space Shuttles and six Titan IVs each year would deposit the same amount of HCl into the troposphere as is produced by the Atlantic Ocean each year in an area of the ocean represented by a square less than 30 miles on each side.[175]

8.1.2. Stratosphere

In the stratosphere, cumulative impacts of rocket launches could *potentially* affect global warming and depletion of the stratospheric ozone layer because chemicals are emitted during launch activities that play a role in these atmospheric conditions. However, the cumulative impact on global warming from rocket launches is insignificant when compared to other industrial sources. Additionally, the cumulative impact on stratospheric ozone depletion from rocket launches is far below and indistinguishable from the effects caused by other natural and man-made causes. Ongoing research in this area indicates that ozone depletion from LV exhausts is limited spatially and temporally, and that these reactions do not have a globally significant impact on stratospheric chemistry.[176] Table 8-2 summarizes both programmatic and non-programmatic emission loads to the stratosphere; note that the load to the stratosphere will be the same as the load to the troposphere (as shown in Table 8-1) because the residence time is assumed to be the same (60 seconds) and the propellant type used is assumed to be the same.

TABLE 8-2
SUMMARY OF EMISSION LOADS FROM PROGRAMMATIC AND NON-PROGRAMMATIC ROCKETS TO THE STRATOSPHERE (TONS)

	HCl	Al_2O_3	CO_2	H_2O	N_2	Cl	NO_x	CO
Programmatic								
US Commercial	5024.3	9048.4	24744.1	10141.3	2001.1	66.99	0	0
Non-Programmatic								
US Government Launches	13108.3	23705.9	35151.7	28087.7	5240.5	174.8	0	0
International Commercial Launches	2504.0	4523.4	15424.4	8110.6	936.9	33.4	9215.4	0
Foreign Government Launches	6801.9	12288.2	42297.1	22101.2	2552.6	90.7	24923.4	0
Total Non-Programmatic	22414.2	40517.5	92873.2	58299.5	8730.1	298.9	34138.7	0

8.1.2.1.Global Warming

The cumulative impact on global warming from rocket launches is insignificant compared to other industrial sources (e.g., energy generation using fossil fuel) and activities (e.g., deforestation and land clearing). The U.S. commercial LV emissions load of CO/CO_2 to the troposphere, stratosphere, and mesosphere is only about 1/4 of the non-programmatic LV emissions load. However, even when accounting for both programmatic and non-programmatic (cumulative impact) CO/CO_2 loads combined, it is infinitely small compared to emissions loads from other industrial sources just in the United States. As Table 8-3 indicates, the amount of CO/CO_2 emissions load from all rockets worldwide over the time period 1998-2009 is 0.0007 percent of CO/CO_2 emissions from U.S. industrial sources in one year.

TABLE 8-3
COMPARISON OF EMISSIONS LOADS OF CO/CO_2 TO THE TROPOSPHERE AND STRATOSPHERE

Emissions	CO/CO_2 Emissions in tons
Programmatic (US launched Commercial LVs) from 1998-2009	49,488
Non-Programmatic from 1998-2009	204,069
Other Industrial Sources in the United States	150,200,000,000 for four years 37,550,000,000 for one year

*Source: USEPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1994.

8.1.2.2.Ozone Depletion

The cumulative impact on stratospheric ozone depletion from rocket launches is far below and indistinguishable from the effects caused by other natural and man-made causes. This PEIS estimates impacts from much smaller LVs than the Space Shuttle, thus air impacts from the Space Shuttle provide a conservative upper bound for comparison.

As Table 8-4 indicates, the emission loads of Cl (both HCl and Cl ion) from both programmatic and non-programmatic launches from 1998-2009 accounts for only 1.6 percent of the industrial Cl load from the U.S. over the period 1998-2009. The vast amount of the Cl load from rockets is as HCl which does not readily breakdown into the ozone depleter Cl. Also, the HCl in the troposphere is usually quickly removed. The emission loads of CL from LV activities is also minimal in comparison to the 400,000 tons of inorganic chlorine created annually by photolysis of historical reservoirs of CFCs.

Almost all of the studies to date on ozone depletion from rockets are based upon homogenous gas phase chemistry which does not address the effects from particulates and aerosols released during ascent. There are no existing models which can predict the effects from particulates and aerosols on ozone depletion caused by rockets. Future analysis of rocket launches using heterogeneous chemistry could significantly alter the understanding of cumulative impacts of rocket launch emissions on stratospheric ozone-depletion. There is some evidence that particulates may play a larger role in ozone depletion reactions than has currently been demonstrated. If this is the case, assuming only homogenous gas phase chemistry (i.e., no effects from particulates or aerosols) would underestimate the amount of ozone depletion actually occurring as a result of emissions from rocket launches.

TABLE 8-4
COMPARISON OF EMISSIONS LOADS OF CHLORINE (HCl AND FREE Cl) IN THE TROPOSPHERE AND STRATOSPHERE FROM 1998-2009

Emissions	Cl Emissions in tons
Programmatic (US launched Commercial LVs) from 1998-2009	10,182
Non-Programmatic from 1998-2009	45,426
Other Industrial Sources in the United States	3,600,000

* Source: Scientific Assessment Paper 1994 data is 300,000 tons/year from 1985-1992 . Assumed rate will stay the same for 1998-2009.

8.1.3. Mesosphere

Due to the brief amount of time rockets spend passing through the mesosphere, there are no cumulative impacts predicted to the mesosphere.

8.1.4. Ionosphere

Water, CO_2, and atomic hydrogen exhaust products from rockets have been found to have a temporary effect on electron concentration in the F layer of the ionosphere. The temporary effect is a “hole” caused by a rapid charge-exchange reaction between the rocket exhaust products and the ambient atomic oxygen ions in the F layer. Not all launches cause a “hole” in the F layer of the ionosphere. Rather, this effect is dependent on the location of the final parking orbit of the vehicle. The more rockets that are launched, the greater the potential for creating “holes” in the ionosphere, resulting in a cumulative impact on the ionosphere from programmatic and non-programmatic rockets. Based on the limited available data indicating that this effect is temporary, however, the cumulative impacts to the ionosphere are considered minute.

8.1.5. Accidents

When an accident occurs near the launch pad or a launch anomaly results in using a flight safety system, there is a cumulative effect on air quality, potential global warming, and stratospheric ozone depletion. Accidents near the launch pad have a more local environmental impact, whereas releases from vehicle destruct via the flight safety system have a potential cumulative global impact. Emissions from the open burn of solid propellant include the following: HCl, CO, CO_2, Al_2O_3, and NO. For vehicles using a liquid hydrocarbon propulsion system (e.g., LOX-RP1) or a hybrid propellant (e.g., solid/LOX), CO_2 would be the largest emissions source of concern. The open burn of hypergolic propellants would result in the formation of NO_2 and NO.

For accidents that occur in the stratosphere, HCl and NO_x emissions could potentially contribute to stratospheric ozone depletion, while CO_2 emissions could potentially contribute to global warming. These effects of an accident on ozone depletion and global warming would be greater with a larger rocket. Although cumulatively, probabilities for accidents increase with the proportionate increase in launches considered, accidents are still rare events. Therefore, the overall cumulative impacts from accidents are insignificant as compared with other emission sources.

8.2. Potential Cumulative Noise Impacts

In general, the potential cumulative impacts of noise from rocket launches are expected to be local rather than global. However, an important possible cumulative noise impact might be changes in the migrating route and habitat choice of certain marine mammals exposed to repeated occurrences of sonic booms from LVs .

8.3. Potential Cumulative Impacts to Local Environments

Any potential for cumulative impacts to local environments is beyond the scope of this PEIS and would be considered in site-specific documentation.

9. MITIGATION

This section addresses broad mitigation measures that may be implemented to prevent or reduce environmental effects associated with the preferred alternative. A complete analysis of specific mitigation measures will be addressed in site-specific environmental documentation required for FAA licensing. In order to ensure that mitigation measures are effective and in compliance with applicable regulatory requirements, appropriate monitoring would need to be conducted at individual launch sites, such as water sampling and analyses, archeological surveys and avoidance of areas with historical artifacts, and biological species surveys by specialists to monitor health and numbers of biological species of concern. Another mitigation activity is the requirement that all launch sites comply with the permit conditions imposed by regulatory authorities. Research is continuing in several areas vital to mitigating potential environmental impacts of LVs, including analysis of the relative merits and impacts of different combinations of propellant systems. For example, research is ongoing into the performance capabilities and environmental attributes of scavenged propellants, neutralized propellants, solution propellants, minimum signature propellants, and HTPE/TEPAL propellants. As additional data on this topic become available, this information should be used to implement appropriate programmatic mitigation measures.

Examples of mitigation measures are described below.

9.1. Noise

Research and guidelines regarding noise harassment and injury are evolving. Launch personnel responsible for environmental health and safety should keep abreast of advances in this area, and take active measures to avoid levels established as inducing behavior modification or injury (e.g., certain sea state conditions may be associated with less noise impacts, as well as certain slower speeds). Possible actions to mitigate the effects of noise at commercial launch sites include:

- Orientating the flame bucket away from sensitive receptor areas.
- Constructing blast fences around the launch site perimeter.
- Restricting launches to optimal seasons (e.g., launching only during non-nesting or non-migratory seasons, depending on the species of concern).
- Using a deflection shoot on the blast bucket.
- Restricting launches to optimal times during the day (e.g., preferably mid-day).
- Planting tall and fast-growing trees around the perimeter of the launch site (e.g., poplar trees).
- Constructing berms along roadways.
- Using lower engine power levels at liftoff, as appropriate.
- Coordinating with U.S. Fish and Wildlife personnel regarding appropriate local activities and monitoring of sensitive species.

9.2. Water Quality

Possible actions to mitigate the effects on water quality at commercial launch sites include:

- Implementing effective storm water pollution prevention plan and permits, updating these plans as needed.

- If surface or ground water is to be withdrawn for fire protection, personnel deluge purposes, noise mitigation, or for potable water studies may be undertaken to ensure the reservoir has an adequate capacity.
- Preparing spill contingency plans that are updated as frequently as needed.
- Containment structures can be constructed around storage facilities to prevent a leak from impacting surface or ground water.
- Contoured land or catchment basins can be put in place to collect excess water from flame suppression or noise suppression activities.

9.3. Air Quality

Possible actions to mitigate the effects on air quality at commercial launch sites include:

- Using environmentally-friendly propellants, as feasible.
- Launching in optimal weather and wind conditions for minimal dispersion of ground cloud.
- Participating in emissions banking programs.

Research is continuing in several areas vital to mitigating the potential air impacts of LVs. As additional information becomes available regarding currently unresolved research questions, this information should be used to implement appropriate air quality mitigation measures. Examples of current unresolved research questions include: (1) the influence of local stratospheric meteorology in ozone depletion related to LV emissions; (2) size distributions and relative influence of alumina versus soot emissions; (3) U.S. LOX/kerosene propellant systems ozone loss mechanism; (4) emissions and potential ozone-depleting differences between U.S. and Russian LOX/kerosene motors; and (5) impacts from emissions from pure (no SRM) LOX/kerosene LV propellant systems.[177]

9.4. Solid and Hazardous Waste

Possible actions to mitigate the effects of solid and hazardous wastes at commercial launch sites include:

- Taking advantage of all pollution prevention opportunities, and implementing an active pollution prevention plan and reward system.
- Implementing a proactive recycling program for solid and some hazardous wastes to minimize the amounts generated.
- Purchasing environmentally-friendly products whenever possible.
- Maintaining appropriate site-specific clean-up materials in accordance with spill prevention and preparedness procedures (e.g., pH neutralizers).
- Developing a comprehensive Environmental Management System consistent with ISO 14000 guidelines.

9.5. Cultural and Historical Resources

The most important mitigation action to protect cultural and historical resources is to restrict activities and disturbances at launch sites, as much as is feasible, to limited areas in order to maintain near-natural conditions on as much of the site as possible. In addition, consultation with appropriate state historic preservation offices, tribal historic preservation offices, local communities, and impacted populations should be conducted to identify and further mitigate possible effects on cultural and historical resources. Specific mitigation actions should include the following:

- Whenever possible, avoid launching LVs in culturally or historically sensitive areas.
- Relocate resources, if possible and approved by stakeholders and public authorities.
- Protect resources from launch impacts with blast fences, enclosures, and other physical control measures.
- Coordinate with the state historic preservation office, tribal historic preservation offices, and other local authorities, as appropriate and meet proactively with members of the public.

9.6 Biological Resources

The most important mitigation action to protect biological resources is to restrict activities and disturbances at launch sites, as much as is feasible, and to limited areas in order to maintain near-natural conditions on as much of the site as possible. Generic mitigation measures should also include proper containment of all chemicals and an adequate spill preparedness program, including effective emergency and disaster plans to minimize the effects of accidents. Specific mitigation measures to protect biological resources at commercial launch sites might also include the following:

- Relocating endangered or threatened animals.
- Banking wetlands.
- Using barriers (e.g., fencing) to minimize animal intrusion in the area or to keep species in place and away from the launch location.
- Building new habitat (habitat substitution) or improving existing habitat.
- Implementing an effective lighting policy for management of exterior lights, emphasizing the use of low-pressure sodium lights as opposed to lights that emit ultraviolet, violet-blue, and blue-green wavelengths.
- Active monitoring (and implementing appropriate action plans using the results of monitoring) to offset any unanticipated effects.
- Optimally directing the launch pad flame duct so as to minimize impacts to vegetation from scorching.
- Coordinating with U.S. Fish and Wildlife personnel regarding appropriate local activities and monitoring of sensitive species (e.g., conducting operations to avoid sensitive breeding or weaning seasons).

10. RELATIONSHIPS BETWEEN SHORT-TERM USES AND LONG-TERM MAINTENANCE AND ENHANCEMENT OF THE ENVIRONMENT

Section 1502.16 of the Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, require that the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity be discussed. For the purposes of this preferred alternative, the launching of commercial LVs and their associated impacts can be considered as the short-term use of the environment. Each launch involves potential atmospheric, noise, land, water, and biological impacts as discussed in Chapter 5. The ground cloud formed from the ignition of rocket motors and the resulting launch of the LV constitute the main potential impacts. Other potential impacts could result from accidents on the launch pad or during flight. With the exception of atmospheric impacts, impacts to most of these media are short-term in nature. Impacts from changes in pH in soil and water typically recover quickly from acid deposition, depending on local conditions. While adverse impacts to plants and wildlife in the immediate vicinity of the launch pad could occur, species in the local area experience minor impacts or are generally unaffected. Commercial LV launches may have a cumulative adverse impact on ozone levels in the atmosphere, but ongoing research in this area appears to dispute that conclusion.

Launching commercial LVs in the U.S. will contribute to the maintenance and enhancement of long-term productivity of the environment in that U.S. rockets generate fewer emissions impacting the atmosphere compared to foreign rockets. As discussed in the analysis presented in Appendix A, a larger proportion of the launches by foreign entities use larger vehicles, which have higher emission rates. Furthermore, for larger payload launches, the U.S. typically uses propellants (e.g., solids, RP1/LOX), which are associated with less emissions of NOx than the propellant typically used for larger payload launches by some foreign entities (e.g., hydrazine). Commercial LVs in the U.S. will contribute to the long-term productivity of the U.S. space industry and its associated industries, such as telecommunications. Each LV launch also contributes to the local economy of the launch facility employed.

11. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The licensing and launch of commercial LVs will enable transport of government, scientific, and commercial payloads (e.g., communication satellites, other spacecraft, scientific experiments) into various orbits around Earth.

The launch of LVs requires the commitment of natural resources, including the consumption of mineral resources. No additional resources, whether human or land resources, are expected to be committed to the launching of LVs beyond those that have been or will be addressed in site-specific NEPA documentation. Basic commitments of resources for the commercial space launch program are not different from those necessary for many other research and development programs. They are similar to the activities that have been carried out in previous space program activities over the past 25 years.

11.1. Natural Resources

Commercial LV launch activities will consume various quantities of materials and energy. This section attempts to estimate, where possible, those natural resources which will be committed as a result of these activities.

11.1.1. Material Requirements

The materials used to manufacture LV flight hardware include a modest amount of metals, such as aluminum, nickel, stainless steel, carbon, copper, titanium, and other materials. These materials are readily available in large quantities. Composite materials or FRP (fiber reinforced plastics) are also used on LVs. Composites may be composed of glass, carbon, or aramide fibers imbedded in resin; specific vehicle structural parts or tanks are then fabricated by winding filaments or tape or laying up impregnated cloth or tape as required by the application. Composite materials are currently being used for wings of the Boeing 777 aircraft. In general, the amount of metal and composite materials that will be required for LV activities is negligible compared to the quantities routinely produced.

Solid and liquid propellants and other consumable fluids will be expended during the launch of LVs. Appendix A describes these materials and their quantities. LVs typically use solid rocket propellants (such as polybutadiene acrylonitrile and aluminum powder) from launch through both the troposphere and stratosphere. Solid rocket motors in conjunction with liquid LOX-RP1 systems, SRMs, or hybrid propellants are also used. During flight through the mesosphere, SRMs, SRMs and LOX-RP1 systems, hybrid, and hypergolic propellants are commonly used.

11.1.2. Energy Requirements

The energy requirements for launching LVs are mainly for ground-based activities during in-flight support.

No substantial increase in energy demand is expected as a result of LV launch activity. The ground-based activities will be performed at existing facilities whose energy needs are supplied by existing utilities. LV launch activities should cause no substantial increase in energy consumption at these facilities.

11.1.3. Changes in Biological Resources

Biological resources in and around launch facilities will be assessed in subsequent site-specific EAs/EISs. No substantial loss of biological resources is expected as a result of LV launches.

11.2. Cultural Resources

No substantial changes to cultural resources, employment, land use, recreational and historical resources are expected.

12. PUBLIC AND AGENCY COORDINATION PROCESS

A Notice of Intent was published in the Federal Register on November 27, 1995 announcing the preparation of a programmatic Environmental Impact Statement (EIS) addressing the potential effects of commercial expendable launches. No formal scoping meetings were planned. However, the notice stated that if sufficient interest was expressed in holding a public meeting, those requests should be forwarded to AST. Although no interest in holding public meetings was expressed, written comments were received, as summarized in Table 12-1. Comments on this Draft PEIS for Commercial Expendable Launch Vehicle Operations were requested directly from federal agencies, industry, and individuals who expressed an interest in being included on the distribution list. Comments received and responses will be included in the Final PEIS.

TABLE 12-1
SUMMARY OF COMMENTS RECEIVED DURING SCOPING

Commentator/Name of organization	Issues Raised
Ms. Robyn Thorson Acting Regional Director Department of the Interior, Fish and Wildlife Service	➢ A drawback of the PEIS is the lack of site-specificity. ➢ Analysis of direct/indirect and cumulative impacts should be included. ➢ Should identify that may expect to have facilities built. ➢ Completion of PEIS should not preclude preparation of site-specific NEPA documents and state and local planning.
Col. Louis D. Van Mullem, Jr., USAF Chief, Environmental Management Vandenberg Air Force Base, California	➢ Scope of the PEIS should include payload and payload constituents. ➢ Scope should include ground, air, and water transportation of pre-assembled launch vehicles.
P.K. Arthur Special Assistant for Space WSMR Flight Safety Space Initiative Office	➢ Omit the word “expendable” on the title page. ➢ Is the EIS a site specific document? ➢ This PEIS does not address recovery operations. ➢ For flight-specific applications, use environmental technical documents tiered to the PEIS. ➢ Recommends adopting over land risk criteria prior to completion of the PEIS. ➢ Legal concern over accountability of DOD employees using commercial standards. ➢ Should define the responsibilities or criteria for determining a lead launch site and co-responsibilities of the Air Force Space Range.
Mr. Robert Andreoli WSMR Mr. Robert Andreoli WSMR	➢ Should address both expendable and non-expendable launch vehicles. ➢ Consider electromagnetic spectrum usage. ➢ Use cumulative impacts information from WSMR, Holloman AFB, Fort Bliss, NASA, and Space and Strategic Defense Command. ➢ Consider effects of light upon the ability to conduct

Commentator/Name of organization	Issues Raised
Continued…	night space observations. ➢ Consider the reintroduction of the Mexican Wolf into southern New Mexico. ➢ Consider effects on local recreation areas. ➢ Consider water use and disposal needs. ➢ Consider air quality pertaining to using optical tracking instruments. ➢ Consider the impact on WSMR operations and land they are using. ➢ Consider present and future air space use by WSMR. ➢ Consider the agreement WSMR has with its neighbors for safety purposes.
Ms. Karen Poniatowski Program Manager, New Programs and Integration NASA	➢ PEIS should be expanded to include environmental effects of a broader number of launches, non-federal government launch sites, a range of payloads, reentry vehicles, reentry of orbital debris, and air-launched vehicles. ➢ The use of "reasonable worst case" to bound environmental effects may not be advisable. ➢ Biological, terrestrial, cultural, and aquatic resource impacts are site-specific. ➢ On page 4-5, the wording and table regarding "fuels" should be "propellants" since oxidizers are included. There should be distinction between amounts of propellants involved or effects of combustion products. ➢ On page 3, 2nd paragraph, a reference to the Army should be included in the last sentence.
Mr. Olin C. Miller Chief, Environmental Flight 45th Space Wing Environmental Flight Department of the Air Force	➢ Can the PEIS be broadened to include generic types of payloads? ➢ Will Evolved Expendable Launch Vehicles (EELVs) be addressed?
Mr. Gregory G.Y. Pai, Ph.D. Director Office of State Planning/Office of the Governor of Hawaii	➢ Issuing commercial launch licenses for any launches in the State of Hawaii should be reviewed for consistency with Hawaii's Coastal Zone Management Program.
Mr. Bill Paulick Alaska Division of Trade & Development	➢ Will the EIS cover platforms such as the Boeing Corp. offshore launch platform? ➢ If the platforms are towed into international waters, will the EIS apply to launches?
Mr. Mike Sirofchuck Citizen of Kodiak, Alaska	➢ It is fair and appropriate to use current information, knowledge, and research in determining suitability. ➢ The licensing of the Kodiak Launch Complex should be delayed until the PEIS is finalized.

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